Volume XV Number 1

JOURNAL of DENTAL RESEARCH

Official Publication of the
INTERNATIONAL ASSOCIATION FOR DENTAL RESEARCH

February, 1935

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PUBLISHED BI-MONTHLY AT MT. ROYAL AND GUILFORD AVENUES, BALTIMORE, MD.
By THE JOURNAL OF DENTAL RESEARCH, Inc.
EDITORIAL OFFICE: 632 West 168th St., New York City
Made in United States of America

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Entered as second-class matter June 24, 1919, at the Post Office at Baltimore, Maryland, under the act of March 8, 1879

WAVERLY PRESS, INC.
BALTIMORE, U. S. A

JOURNAL
of
DENTAL RESEARCH

Official Publication of the
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Volume Fifteen
New York
1935–1936

JOURNAL
of
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Official Publication of the
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FUTURE OF THE JOURNAL OF DENTAL RESEARCH

QUOTATIONS FROM ANNOUNCEMENTS IN THIS VOLUME

An addendum to a similar summary of announcements, on page iv of Vol. XIV, indicated that the Permanent Board of Editors was then (December, 1934) selecting its officers and determining its procedure.

June–August, 1935. "After adopting a group of guiding principles in the nature of by-laws," the Permanent Board of Editors placed "the active editorship in charge of an Executive Committee of three, to be aided by a Finance Committee of three. The members of the Executive Committee, as very recently selected, are Theodor Rosebury, *Editor*; Edward H. Hatton, *Associate Editor*; Paul C. Kitchin, *Assistant Editor*." During the initial phase of the balloting by the Board of Editors for the position of Editor, the General Secretary, who had previously been Editor, was designated to continue in that position. He requested, however, that a younger man be elected to succeed him and offered to cooperate by serving in a temporary subordinate position. The Board of Editors having assented to this suggestion, the General Secretary was "selected to serve as *Temporary Second Assistant Editor*, pending completion of the reorganization, and the successful initiation of the new editorial management. The members of the Finance Committee, also the three trustees of the Association's endowment fund, are Bissell B. Palmer, *Treasurer*, Arthur D. Black and Russell W. Bunting" (p. 228).

The report of the Executive and Finance Committees, after a joint session at the general meeting of the International Association for Dental Research in March 1935, recommended (a) that Dr. Rosebury (Editor and Chairman of the Executive Committee) be elected chairman of the Board of Editors, and Dr. Gies, Editor Emeritus and a permanent member of the Executive Committee of the Board of Editors; (b) that "the *Journal* carry permanently on its front cover (title page) the legend: 'Founded by William J. Gies

in 1919;' (c) that advertisements be included to increase the *Journal's* income, "such advertisements to conform to the stipulations of the Code on Advertising adopted by the American Association of Dental Editors;" and (d) that various measures to "place the *Journal* on a permanently sound financial basis, be put into effect by the Finance Committee" (pp. 229–30).

"This report of the joint committees was adopted, by the Association, subject to confirmation of all matters of policy by the Permanent Board of Editors, to give all sections of the Association opportunity to participate in the final decision. This confirmation was given by unanimous vote of the editors, and so announced by the Chairman to all members of the Board" (p. 230).

September, 1936. "The *Board of Editors* reported (a) that all proposals, in the report of the Executive and Finance Committees at the meeting of the Association in 1935, had been confirmed by the Board (*J. Den. Res.*, 1935–36, *15*, pp. 229–30); (b) that Dr. Theodor Rosebury had been unable effectively to inaugurate his duties as Editor, having ultimately resigned as of December 17, 1935; and that the Finance Committee had not materially increased the resources of the *Journal.* The ensuing embarrassments led, after active discussion, to adoption of the following resolution: *Resolved,* that the affairs of the *Journal of Dental Research* be placed in the hands of a Committee to consist of H. C. Hodge, M. K. Hine, and H. B. G. Robinson; and that the Board of Editors be continued for the year 1936–37, to make further recommendations at the Fifteenth General Meeting on the future of the *Journal of Dental Research*" (pp. 377–78).

"*Journal of Dental Research:* now the Association's official publication. . . . . Difficulties attending the development of a new editorial management . . . made it expedient to combine the delayed bimonthly issues for 1935, with two quarterly issues in 1936, into one volume (XV) for 1935–36." (Cover, page 3, Sep. and Dec., 1936.)

December, 1936. Endowment Fund: A general plan for its development has been announced by the Chairman of a special committee, Dr. Arthur H. Merritt, 580 Fifth Avenue, New York City (pp. 457–59; Supplement).

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JAWS AND TEETH[1]

ALEŠ HRDLIČKA, M.D., Sc.D.

U. S. National Museum, Smithsonian Institution, Washington, D. C.

I am always glad to address the more scientifically inclined members of the dental profession, for among them are many earnest and able students who represent a field of knowledge and activities that are steadily growing in importance. Dentistry among civilized peoples is assuming increasing importance, and is already a very essential part of public health and welfare. If the results of anthropological research, on the parts that dentistry deals with, can be of any assistance in the solution of its problems, they are freely at its disposal. The related advantages of anthropology—particularly in this country—are due to the fact that its attention is directed toward the normal, non-pathological, conditions of the jaws and teeth; and that it now has at its disposal vast collections of skeletal material, extending over a great stretch of time and representing all the more important races. Anthropology may thus be expected to help dental science in elucidating the basic normal conditions and laws relating to the jaws and denture. Regrettably the aid must be limited, owing to a dearth of able workers dedicated to studies of these structures. From what has nevertheless been possible in this direction, there loom up the recognitions which will now briefly be laid before you.

The more the problems of the human jaws and teeth are studied, the more complex they are realized to be. It would be vain, therefore, to hope that any new contribution to these studies would simplify matters for the dental profession. All that can be expected, by those who follow the scientific aspects of dentistry, is more mental work and more research; although this, they may be confident, will bring more light, and eventually the possibility of more effective performance of their tasks. Dentistry deals, in the first place, with the

[1] Address at a meeting of the Washington Section of the International Association for Dental Research, May 3, 1934.

teeth; in the second place with the *jaws*. Perhaps the first question is: Which of these two formations is the more subject to such derangements as come to your attention and demand your assistance? In organic evolution, the jaws developed gradually from the mesoblastic tissues; they were brought forth for the growing needs of the mouth, and in a primitive form were there before the teeth. In the beginning they were probably but cartilaginous sustaining structures; but then they developed grasping and crushing properties, which facilitated primitive chewing, and thus became the earliest representatives of the masticatory apparatus. Only after this there could have begun to develop, from the epithelium of the mouth, accessory features for better holding, moving, piercing, crushing, and triturating food. These features were in the form of spines, rugosities, horny ridges, horny lips, bony nodules or plates—finally, definitely differentiated accessory organs, the true teeth. The first teeth were realized, it seems, in ancient sharks and fishes. They were already greatly developed in some of the pterodactyls and some early lizards. But they were still all conical, more or less spine-like, and doubtless primitive in other respects.

Teeth with true cusps do not appear, apparently, much before Cretaceous time. They are essentially the teeth of mammals. The old simple cone has given rise, through stages that have not yet been recovered, to another pattern; namely, the triconodont or three-cusped form, from which eventually developed all the greatly varied cusped teeth of mammals. And among these, from the Eocene (the beginning of the Tertiary age) there begin to appear in certain ancient small arboreal species, classed today as the *Prosimiae*, teeth that are differentiated regionally into *I*'s, *C*'s, *Pm*'s and *M*'s, teeth that probably have already two phases of eruption, and in which the molars show four cusps. There have been reached the Primate teeth, from which it is only a moderate step to the human. The teeth, therefore, were somewhat later formations than the jaws; and the distinguishing or specific characteristics of human teeth are fairly recent. But as the teeth were differentiating so were the jaws, and the changes in the jaws corresponded, under normal conditions, on one hand to the spatial and other demands of the teeth; on the other, to the amount of work of the masticatory apparatus. It is therefore possible to stipulate, on the basis of evidence of organic beings having teeth, that

while strictly speaking the teeth are not the progeny of the jaws but are formations added to the latter, yet there exists throughout, under normal conditions, a close correlation between jaws and denture. When matters are looked at more intensively, however, it is found that the teeth correlate essentially with the alveolar processes, and much less so with the jaws proper. The real amount of correlation between teeth and jaws reaches only so far as the jaws are obliged to accommodate and sustain the alveolar processes and the tooth action.

This leads us to the *first* realization of importance, which is, that jaws and teeth are not the same but only coördinate entities, of different embryological derivation, and that their unity is really but a sort of symbiosis or intimate coöperation. This explains why the jaws proper, outside of the alveolar processes, retain individuality in shape, size, and other respects—in other words, they may vary phylo- or ontogenetically, to an extent, independently of the teeth. In consequence of this there may occasionally be larger or smaller, higher or lower, more slender or heavier jaws—the mandibula in particular—with practically the same size of teeth; and there may be other disharmonies. Such incongruities are not infrequently attributed by dentists to differences in inheritance from the two parents or from the two sides of the family; the possibility of such inheritance, experience teaches, is remote and no such explanation of any given case could be legitimate without convincing demonstration.

Not only may the jaws vary more or less independently of the teeth, but they may vary differently in their separable constituents or dimensions. Thus the variability of the chin region is distinct from that of the body of the mandible; that of the body partly distinct from that of the ramus; that of the latter at least partly distinct from that of the notch or the condyles. Though they all correlate more or less, yet every feature of the lower jaw, as well as every feature of the upper jaw, has also a certain individuality. There may thus be wide differences in height, breadth, and conformation of the ramus without fully or even largely corresponding conditions of the body; and vice versa. The basic correlation of the different parts and features of the jaws may be more or less altered by influences that have acted more directly or strongly on some parts than on others. This is a *second* consequential realization.

The *third* fact is that the teeth, and everything connected with

them, vary greatly individually, even under the most normal and uniform conditions. They vary in time of eruption, as is well known to all. But what is not generally realized is that each unit of the dental arch, while again fundamentally correlating with the others, has nevertheless also some quantum of individuality—and particularly, perhaps, as to the complex phenomenon of eruption. Thus far the main attention has been given to the average time of eruption of the different teeth; in the future this must be replaced by a knowledge of the carefully determined normal range of variation for the eruption of each dental unit. This will give the dentist a clearer understanding of the related manifestations that will confront him in his different patients. Besides the normal variations in the eruption of the different teeth there are, too, those that are due to abnormal conditions. For the orthodontist, above all, the subject of the abnormal variants in tooth eruption—of undue delays, in particular—is of the greatest practical importance, for such delays and disorders are the chief causes of displacements of teeth, of irregularities of the dental arch, and of malocclusions. Aside from eruption, human teeth vary also normally, as well as abnormally, in size, shape, mass, cuspids, enamel, roots, blood supply, innervation, and in every other particular—with more or less individuality for the different items. They also doubtless vary in their resistance to disease. Take, for example, the first and second permanent lower molars. Meticulously careful measurements show not only a substantial individual normal variation, but also differences of variability in the two sexes. Similar measurements show material variation in all the rest of the teeth, even if the specially variable lateral incisors and third molars be left out of consideration.

The above is a condensation of the main theme which, in this address, I wanted to impress upon you; and that is the existence, under even the most normal conditions in both jaws and teeth—and in each constituent of these—of a range of normal individual variation. In addition to this there exist sex, age, and racial differences, and differences due to abnormal conditions. Thus not only each individual jaw and set of teeth, but each individual tooth and feature of jaw or tooth, presents its own problems that call for intelligent appreciation, and may affect your attitude in dealing with them. The subject is

charged with details. A major part of it is known only very imperfectly, and will demand profound and prolonged studies. Naturally, not all the details will be of use or consequence to dentistry. But the importance and interests of dentistry demand an ever more general and fuller appreciation of these conditions.

The object of these few informal remarks is to help to widen the horizon of the dental student, and to aid him with the results of investigation in the biological sciences, on the jaws and teeth. It is to impress him with the modern view of all living entities, jaws and teeth included, which shows that these entities, even under the most normal conditions, are not stable, definite, standard features, but instead just so many variables. It follows, except in a very general way, that the jaws and teeth of any given subject must, in the practice of dentistry, always receive individualized study and attention.

DISCUSSION

H. E. Kelsey, D.D.S., F.A.C.D. (Baltimore, Md.): While close and careful observation by me, during many years, of nearly 2000 cases of malocclusion of the teeth—usually accompanied by more or less pronounced maldevelopment of the jaws—may be regarded as an investigation of at least one phase of the subject indicated by the title of Dr. Hrdlička's paper, it is completely lacking in the data which can be supplied only by men like him, who have at their command a wealth of skeletal material such as is contained in the National Museum. It is true that progress is slow and unquestionably made slower by the fact that one civilization often undoes what another has accomplished, but enough has been preserved in the ruins of nearly all past civilizations to enable the archeologist to piece together a fairly satisfactory history of their culture. We, as a profession, have not availed ourselves as fully as we might of the wealth of information to be obtained in such a museum as the National, under the conduct of such men as Dr. Hrdlička. His paper, giving the result of long and conscientious research in a field which is of the utmost importance to us, increases our indebtedness to him. It treats of one of our most perplexing problems, and it is a satisfaction to know that some of our clinical difficulties arise from causes which have been noted by investigators in collateral fields. In efforts to standardize our practice, we have all had disappointments when the introduction of various new methods or systems of practice have intrigued us with the hope that we had arrived, at last, at a point where every individual could be put into a class in which he would react to our treatment

exactly as did some other individual who presented the same clinical picture. We have hoped much from the claims of these enthusiasts, and often without doubt have learned a great deal; but in the end, we have generally discovered that our percentage of success or failure has not been greatly altered. In other words, the individual normal may present a variation from the species normal, which when unrecognized is sufficient to upset any complacent prognosis.

Every practitioner of wide experience can remember with what satisfaction he completed a particular case in which he was lucky enough to have adapted the treatment to the requirements of the individual, and also the disappointment he experienced when, after enthusiastically administering exactly the same treatment to another individual—who appeared to have a similar condition—there was either a failure or a relapse for which he could account neither by lack of coöperation from his patient, nor incapacity to administer the treatment as he had in the previous case. Almost all of us can remember a time, in our early professional lives, when we felt assured we had absorbed such information as would enable us to classify, diagnose, and successfully treat any case which came into our hands; and when a case did not respond to our standardized efforts, we could only believe that the individual was suffering from the affliction of original sin. It was only later in life, when greater experience had been acquired and we had been aided by research in collateral fields, that we began to understand that our efforts to supplement natural development, or bring about repair in the organs of the individuals, were subject to just as much inequality in results as were Nature's own efforts along the same lines. We, like Nature, must do the best we can with the material at hand, not expecting that each individual possesses inherent possibilities for the development of the ideal.

Dr. Hrdlička has made it very clear that even among primitive races, where the individual was far less likely to be affected by environmental and even hereditary influences than in civilized life, there is conspicuous variation. For instance, there is always the strongest, weakest, most cunning, or most intellectual man. If, therefore, qualities of character and physique in general show conspicuous variations, is it not necessary to believe that there are variations in the different organs of the individual; and if this is true, why should we suppose that the structures constituting the dental organ are exceptions to the rule? Yet in the past, we have seemed to labor under this delusion. In all branches of dental practice, certainly in orthodontia, we have usually based our treatment upon this erroneous assumption. Fortunately the percentages of success in dental and orthodontic practice have been high enough to encourage us to continue our

efforts. When we learn to estimate with greater precision the possibilities of treatment in the individual case, our percentages of failure will be much less, because we will not often be led to make promises which cannot be fulfilled. Our ability to discern variations—one of the most important phases of diagnosis—will hereafter depend as much upon the research of men like Dr. Hrdlička as upon clinical observation. By conscientiously devoting ourselves to study of variations in our patients, and of the results achieved as they pass through our hands—together with the findings of research to which I have already alluded—it is not too much to believe that we may evolve an etiology, fortified by a knowledge of individual variation, that will enable the practitioner to make a satisfactory prognosis of most, if not all, cases as they present for treatment.

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DO RAT MOLARS GROW, DIAMETRICALLY, AFTER ERUPTION?

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Donaldson and French (1927) interpreted tooth measurements on 87 albino rat skulls in the Wistar Institute collections—which showed larger diameters in the older rats—as indicating growth. Wood (1928) urged extreme caution in accepting their interpretation. Wood and Wood (1931) published measurements on the teeth of 7 living Wistar stock albino rats, made at intervals during life, which showed no evidence of such post-eruptive, diametric growth, and concluded that the discussion might be closed, until repeated measurements on some particular rat should show growth. Donaldson (1934) reinvestigated the subject, not through such consecutive measurements on individual rats, but by means of additional and more refined measurements on cleaned skulls. Donaldson's high authority on the rat makes it necessary to evaluate his latest contribution.

It appears to be agreed that the teeth shrink about 1 percent on cleaning; that they average larger in males than in females; that the apparent increase in length of the tooth row in Donaldson's rats is not due to shifts in position of the individual molars; that Donaldson's results are not due to shifting loci of measurement; and that runts tend to have small teeth. Donaldson (1934, p. 344, Table 6) gives useful data on this last point.

The original group of 87 rat skulls was interpreted as indicating diametric growth of the teeth chiefly in rats older than one year (Donaldson and French, 1927). Donaldson's latest study of 180 skulls (1934) restricts vigorous tooth growth to rats aged 37 to 64 days. He considers (1934, p. 342) that "the probable explanation of the earlier results lies in the lack of refinement in those measurements." Their sliding-dial compass, graduated to 0.1 mm., should have given adequate results for the total length of the molar row, a matter of 6

to 7 mm. It is difficult to see how this relative lack of exact instrumental precision could cause growth, now assigned to the second month, to have registered in the second year. Donaldson does not appear to have checked his explanation of this discrepancy by remeasuring the first set of skulls according to his later technique. One criterion of a valid experiment is that anyone who repeats it confirms the result; yet Donaldson fails to confirm his and French's statistical result. An alternative explanation for this discrepancy lies in different modes of selection for the two small groups. Thus another small sample might suggest vigorous growth in the sixth month; while a fourth, with some other unrecognized bias, might show progressive shrinkage. Obviously, a statistical study can be valid only if each of the various classes contains enough individuals for a random sample, and if the material as a whole is not biased as to the particular point under investigation. Donaldson (1934) considers his groups of ten individuals statistically valid, since they give rather uniform results. However, no accepted field of statistical work (e.g., genetics, death-rates) would base a conclusion on eighteen classes of only ten individuals each. Whether random errors are negligible, or not, such small groups leave full opportunity for constant errors. The skulls used by Donaldson and French (1927) were from a series of rats previously selected as typical for their ages, thereby presumably reflecting the selector's choice of body size (in relation to age), with which tooth-size is positively correlated. The unusual uniformity inside the groups in Donaldson's latest study (1934) suggests the operation of a similar form of artificial selection, either in the original material or in the choice of individual rats from the group. Wood (1928) suggested that natural selection might explain the data of Donaldson and French (1927). Donaldson (1929) answered that "if these differences were attributable to the greater chance of survival of the larger animals, with correspondingly larger teeth, to the higher age series, one would expect to find some rows in the younger group giving measurements as great as those in the older group. . . .In no case in the young animals does the row with the greatest length equal the row with the least length in the old group." Whatever bearing this may have on natural selection, it permits positive affirmation that Donaldson and French did not have a random sample. That some

young individuals have larger teeth than most older ones is common information for mammalian tooth measurements, in general. The same thing is demonstrable for albino rats (Wood and Wood, 1931, p. 172), as our young animals yield many measurements comparable with those of our, and of Donaldson's, old animals. Although we indicated that Donaldson and French did not have a random sample (Wood and Wood, 1931), it should have been stated more emphatically. Whether natural or subconscious selection was chiefly responsible for the earlier data (Donaldson and French, 1927; Donaldson, 1929), Donaldson (1934) has now eliminated natural selection as a major factor, as growth is indicated chiefly in the second month, before any sufficient mortality occurs. Donaldson (1934, p. 342) believes that selection is eliminated as a possibility, because "in the present study the individuals forming a group were selected from among normal animals, according to age, not by myself, but by another person unacquainted with the purpose for which the rats were to be used." This would eliminate selection with the desired results subconsciously in mind, but it would not, especially with such small groups, prevent subconscious selection on some other basis which might be associated with tooth-size. For example, if the percentage of college students in the populations of Hanover, N. H., Northampton, Mass., and Princeton, N. J., were tabulated, even if whoever chose the towns did not know for what purpose he was selecting them, the results would be highly misleading for the United States as a whole. Fortunately, speculation as to the possible subconscious motivation of the selector, or about some conceivable bias in the material, is superfluous. Donaldson states (1934, p. 342) "that animals with large teeth did not appear in the younger groups is shown by the graphs for the maximum values within each group, in charts 7–52." I agree that his material shows this relation, proving that his new material also is not a random sample, as such a young animal (rat D) with extra large teeth appeared even among our seven animals (Wood and Wood, 1931; Tables 1, 2 and 5). Donaldson shows that the teeth are generally larger with age, within the set of skulls dealt with, suggesting some fairly uniform cause; but artificial selection of his material could also give this result, and would be in agreement with the other lines of evidence.

Wood and Wood (1931, pp. 173–174) summarize the histology and morphogenesis of the rat molar, which make its continued growth —particularly growth of the enamel—almost inconceivable. Donaldson (1934, p. 342) considers that "this begs the question, and need not be considered." The facts that no mechanism is known by which a process can occur, and that such a mechanism would conflict with known facts, have been regarded as legitimate *a priori* arguments against, for example, inheritance of the effects of use and disuse, prenatal impressions, and telepathy. In view of the conflict between each of these concepts and established generalizations, it would usually be held that far more evidence would be required to establish one of them than to prove, for example, that the gorilla, like man and the macaque, had 48 chromosomes; or that a newly discovered fossil ape had the customary dental formula: $\mathrm{I}\,\frac{2}{2}\ \mathrm{C}\,\frac{1}{1}\ \mathrm{P}\,\frac{2}{2}\ \mathrm{M}\,\frac{3}{3}$.

Donaldson (1934, pp. 343–344) discusses the successive measurements on seven individual rats, made by Wood and Wood (1931, Tables 1–6). As Donaldson and French claimed growth principally in rats over a year old, we concentrated our measurements on that period. Since Donaldson (1934) now claims growth principally in, and immediately following, the second month, he eliminates four of the animals measured by Wood and Wood. His tabulation of their data (Donaldson, 1934, Table 5, p. 344), thereby limited to three animals, is further reduced by omitting intermediate readings between first and last (*e.g.*, he gives only the first and last of the series: 3.58, 3.60, 3.56, 3.53 mm.); by omitting the lower teeth; and by departing from his policy of averaging readings for right and left sides, when full series are not available.[1] Even with all these omissions, which decrease rather arbitrarily the force of the original data, Donaldson's table (1934, p. 344) based on our measurements hardly warrants his

[1] Thus his comparison of 6.93 to 7.08 mm. for the right upper molars of A, showing 2.1 percent "growth" could, by averaging the left side, with the first measurements seven weeks apart, be made to read 7.08 to 6.99 mm., showing shrinkage; and, similarly, for rat B, his 6.65 to 6.90 mm. would become 6.65 to 6.78 mm., showing less than 2 percent "growth," instead of 3.7 percent. Donaldson includes only measurements on impressions. As he seems skeptical about the exactitude of the impression technique, he might have compared such successive direct measurements as 2.98 with 2.91, 2.92 with 2.92, and 1.90 with 1.91 mm., on rat Z, in which growth is notably absent. The original tables should be consulted for full statement of the relevant data (Wood and Wood, 1931, Tables 1–6).

interpretation, but on the contrary indicates absence of any growth. Donaldson indicates by "H" and "L" which of our initial measurements he considers high or low compared with his data, which presumably means that he considers them probably erroneous in the directions indicated. This implication has several extraordinary features. Thus for width of the first upper molar at 47 days, he considers 2.09 mm. as low for A, whereas he considers 2.14 mm. as high for her sister, B, at the same age. If Donaldson has data indicating that the width of the first upper molars of sister albino rats may not vary 0.05 mm. at the same age—a difference of less than 2.5 percent—he should make them generally available. I frequently find much larger percentage differences between homologous measurements on the right and left teeth of the same animal (*e.g.*, Wood, 1934, Tables 1–6). Presumably he means that one value is above, the other below, his average; but that average is, of course, obtained merely from a group of such individual measurements, and has no independent existence or validity of its own. Donaldson (1934, p. 343) also regrets that, in our data, "in the one instance (A; *M* 1 width) where the initial value was low (L), the final value was also very low, thus giving but a slightly plus percentage." The whole series, 2.09, 2.10, 2.08, 2.11 mm., of which Donaldson cites only the first and last, seems rather to indicate a high degree of consistency in a difficult measurement.[2] Donaldson (1934, p. 343) considers our figures as tabulated by him (p. 344) too variable to warrant our conclusion. As stated above, the variability on the positive side, suggesting growth, is introduced to a large extent by the particular data excerpted. Thus the apparent growth of the upper molar series of B can be partly matched by apparent shrinkage,

[2] Such growth, if present, should be a general mammalian character, since it is also suggested for man (Léger-Dorez, 1908, and Tigri, 1851), peccaries (Klähn, 1922), pigs (Beust, in Donaldson, 1929, and Beust, 1930), cats (Donaldson, 1929), and captive gray Norway rats (Donaldson, 1934). The Wistar Institute recently established an opossum colony. As opossum jaws gape widely, and therefore do not present the mechanical difficulties found in measuring the teeth of anaesthetized rats—and as the clear-cut tooth cusps are not seriously obliterated with advancing age—it would be interesting to have consecutive direct measurements, during life, of the dimensions of individual opossum molars at points identifiable in relation to specific cusps, as a check on the alleged growth factor. An interesting sidelight, so far as human teeth are concerned, is the fact that orthodontists are able to leave the same bands on the teeth of children and adolescents over a period of years.

on both sides, of E's upper molars. Even limiting our data to Donaldson's abstract (1934, p. 344, Table 5), the positive values total 7.9 percent for five measurements; and the negative values, 7.4 percent for three items. The positive *percentages* are: 2.1, 0.9, 3.7, 0.3, and 0.9; the negative: −1.5, −2.6, and −3.3. It is obvious that manipulative errors of the order indicated by these percentages would have entirely failed to mask a uniform growth factor of 10, or even 7 percent. Finally, Donaldson (1934, pp. 343–344) objects that "the method used by Wood and Wood tended to give high initial values, and thus to obscure any growth changes with advancing age." I am unable to understand this criticism. Does it mean that impressions are looser on the teeth of young animals? If so, why should they be, and what is the evidence? Or does it mean that our technique or data *must* be inaccurate in failing to substantiate the growth hypothesis? Donaldson claims that growth is sufficiently general in rats to appear, on statistical analysis, to the extent of 10 percent in the original study, and about 7 percent in Donaldson's latest paper. It is significant that the growth factor fails to appear in those particular Wistar stock albino rats subjected to the crucial test of successive measurements during life. The fact that impressions made at any age fit closely over the tooth row in the cleaned skull, and not over the corresponding row of any other skull, litter-mates included, supplies a check, quite independent of measurements, of the absence of growth. Wood and Wood (1931, p. 183) concluded: "If anyone still believes that a larger series might give a different result, the technique has now been worked out, and as many can be measured as may be desired. Unless and until this be done and contradictory results found, it would seem that the discussion might be considered closed. If there is no growth in any one of seven individuals, it seems to be the duty of a skeptic to find at least one individual (not a group of averages) in which actual tooth growth can be demonstrated." Donaldson has entirely failed to meet this challenge.

Summary. 1. The rat tooth measurements analyzed statistically by Donaldson and French (1927) and Donaldson (1934) do not appear to be random samples, but on the contrary show evidence of artificial selection. These two studies, by flatly contradicting each other as

to the age at which the supposed growth chiefly occurs, show the unreliability of the approach.

2. Donaldson (1934) has not refuted, nor even considered, our cogent *a priori* objections to the growth hypothesis.

3. Consecutive measurements on individual rats (Wood and Wood, 1931, Tables 1–6) fail to show any growth factor. Donaldson apparently regards our work as inconclusive because it conflicts with the growth hypothesis; but he completely fails to show growth in a single, individual rat.

4. As previously stated with fuller data and discussion (Wood and Wood, 1931), the supposed diametric tooth-growth remains essentially refuted.

LITERATURE CITED

BEUST, T. B. 1930 Tufts and lamellae in their relation to post-eruptive form changes in the enamel. *J. Amer. Dent. Ass.*, XVII, 4, pp. 624–629.

DONALDSON, H. H. 1929 On the growth of the molar teeth after eruption in the albino rat and in the cat. *J. Den. Res.*, IX, 3, pp. 285–287; with discussion by T. B. Beust.

——— 1934 On the increase in the diameters of the molar teeth of the rat after eruption. *Ibid.*, XIV, 5, pp. 323–346; advance abstract, *Ibid.*, XIV, 3, pp. 158–159.

DONALDSON, H. H., AND FRENCH, H. E. 1927 On the growth in the diameters of the molar teeth of the albino rat, after eruption. *Anat. Rec.*, XXXIV, 5, pp. 277–299.

KLÄHN, H. 1922 Die badischen Mastodonten und ihre süddeutschen Verwandten; 8 vo., pp. viii–ix; Gebrüder Borntraeger, Berlin.

LÉGER-DOREZ, ——. 1908 Les dents humaines changent de forme et de volume depuis l'éruption jusqu'à la mort. *Schweiz. Vierteljahr. f. Zahnheilk.*, XVIII, 2, pp. 107–112.

TIGRI, A. 1851 Sul perenne accrescimento dei denti umani. *Gazz. med. ital. feder. tosc.*, Firenze, (2), I, 73, pp. 578–580.

WOOD, H. E. 1928. Alleged increase in diameter of albino rat molars after eruption. *J. Mammalogy*, IX, 1, pp. 67–69.

——— 1934 Revision of the Hyrachyidae. *Bull. Amer. Mus. Nat. Hist.*, LXVII, 5; Tables 1–6 (pp. 278–289).

WOOD, H. E., AND WOOD, F. D. 1931 Refutation of the alleged diametric growth of erupted rat molars. *Anat. Rec.*, XLVIII, 1, pp. 169–183.

ELECTRICAL CURRENTS AND BUCCAL CANCER[1]

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Considerable evidence in the recent literature on electrical currents in the mouth shows that dissimilar alloys, in certain cases, may give rise to changes in the mucosa characteristic of precancerous or malignant disease. A study of other factors of known importance in the etiology of buccal cancer suggests a division into two classes; namely: (1) systemic, predisposing factors, such as syphilis, senility, and vitamin- or dietary-deficiencies; and (2) locally irritant factors, such as tobacco, bad teeth, poorly constructed dental plates, etc. Since none of these several factors alone, even in excess, invariably results in malignancy, it is possible that the inconsistencies of cancer formation may be due to association of a systemic factor with one or more local irritants. Unless buccal mucosa is rendered susceptible to atrophic changes by a predisposing combination of circumstances, it is probable that neither leukoplakia nor carcinoma results from local irritation alone.

Electric action between dissimilar dental alloys must be added to the group of local irritants in any study of cancer etiology. Previous investigators have tried to correlate the amount of current, recorded by an ammeter when in contact with dissimilar alloys, with the extent of tissue injury. But it is obvious that this current has no relation to existing electrogalvanic action, in the mouth, when the ammeter is disconnected from the restorations. Others have emphasized that dissimilar-metal replacements—generally gold and amalgam—must both be present to induce a current. This, however, is not necessarily true of an amalgam filling. Amalgam is a eutectic-like structure and not like a solid-solution alloy, being composed of minute crystals of copper, zinc, mercury, etc. When such a filling is bathed

[1] Abstract of a preliminary report read before the Boston Section of the International Association for Dental Research, December 10, 1934.

by saliva, all elements necessary for galvanic action are present. Clinical observation of so-called "electric burns" of the oral mucosa suggests that most of such lesions result, more probably, from local action about an amalgam restoration than from a longer galvanic circuit between different teeth containing dissimilar alloys. The tissue injury resulting from such electric action is not yet understood. Since, however, there must be a fairly high concentration of metallic ions locally in the saliva from the dissociation of the positive electrode, it is suggested that in some cases local metallic poisoning of mucous membrane is thus produced. On this theory, a relatively high concentration of the metals used in the restorations should be found in the tissues showing such lesions. Related experimental findings have not yet been completed in our laboratory.

A SIMPLE METHOD FOR GROWING ANAEROBES

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Recently the relationship of anaerobic bacteria to oral pathologic processes has become increasingly more evident. In view of the importance of this relationship to the practice of dentistry, and to many unsolved problems, it is desirable that these organisms be further investigated. To facilitate such study, we present below a simple modification of Sellard's technique,[1] by which anaerobic conditions can be satisfactorily secured from the spontaneous combustion of metallic phosphorus (P). In the method to be described, only standard laboratory equipment is used; the apparatus can be rapidly assembled. The equipment and materials needed are (*fig. 1*) a Novy jar or one of similar construction, rubber stopper, asbestos shield, porcelain crucible, glass tube, cylindrical wire screen, pint Mason fruit-jar, metallic P, and a long slender pipette with rubber bulb.

P, safely double-sealed in pound tins, may be secured from Merck's laboratories. These tins are opened under *cold water* (P burns spontaneously in air, and on contact with hot water ignites with almost explosive violence) and the contained sticks are transferred under water to the Mason jar, which is then turned to the upright position so that it may *fill completely* with water, the cover screwed on tightly under water, and the jar removed. The Mason jar conveniently holds the entire contents of a pound can of P, which is sufficient to produce anaerobic conditions several hundred times. The jar should be stored in a cool, dark place—ice chest or refrigerator, if possible—and the contents removed *always under water*, a stick or portion of a stick at a time as needed. In using this technique the plates and test tubes of liquid or solid media are inoculated in the way they would be for the cultivation or isolation of aerobic bacteria, and placed in the

[1] Sellards, A. W.: Some researches on anaerobic cultures with phosphorus: *Zentralbl. f. Bakteriol., I. O.*, 1904, *37*, 632.

Novy jar. From 12 to 15 petri dishes can be stacked in the center; around them there is sufficient room for from 25 to 30 upright test tubes. After the base of the jar is charged with media, a circular

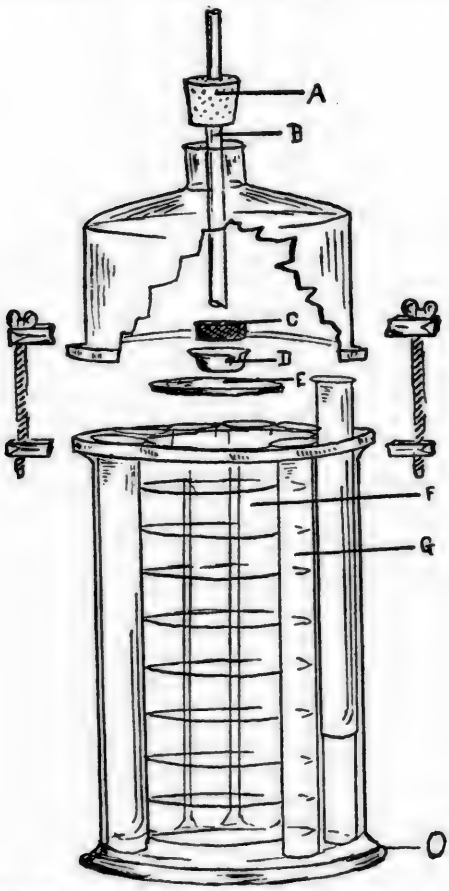

FIG. 1. NOVY JAR, SHOWING PARTS IN MODIFIED SELLARD TECHNIQUE

A—Rubber stopper. *B*—Glass tube. *C*—Cylindrical wire screen. *D*—Porcelain crucible. *E*—Asbestos disk.

piece of asbestos (*E*) is laid on the top petri-dish to prevent downward transmission of the heat generated by the burning of P.

From the head of the Novy jar, the air-exhaustion apparatus is

removed and replaced by a rubber stopper (*A*), through which a glass tube (*B*), a quarter of an inch in diameter and several inches long, has been inserted. The rubber gasket being lubricated, the jar is now ready to receive its charge of P. The combustion chamber is prepared by placing the cylindrical wire screen (*C*) in an upright position in the porcelain crucible (*D*), and partially filling it with coarse clean sand. The chamber is then placed under water with the Mason jar containing P. The jar is opened, a stick of P removed, and with a knife a small portion—a quarter to a half inch long—is cut off and placed in the porcelain crucible on the sand within the wire screen. This crucible, with water covering the P, is placed on the asbestos disc (*E*) over the top of the base of the jar. The head of the jar is placed in position, rotated so that the glass tube passing through the stopper has direct access to the water in the crucible, then clamped in position. There is no need for rush or hurry, for the P will not ignite until the water is removed. When ready, the long pipette (with rubber bulb attached) is thrust through the tubing, and the water in the crucible drawn off. P directly ignites and rapidly consumes the free oxygen. Air rushes through the tube, and P continues to burn so long as there is ingress of air. The pressure within the jar soon comes to equilibrium with that of the atmosphere, and the air-influx ceases; the oxygen is depleted and the P flame is spontaneously extinguished. Owing to the small caliber and length of the tube (*B*), diffusion through it is negligible, and the P once extinguished rarely, if ever, reignites; however, if leaks develop or diffusion occurs, the P automatically depletes the incoming oxygen before it affects the anaerobic integrity of the chamber.

After the combustion has ceased, the apparatus is ready to be placed in the incubator. Following incubation, water is reintroduced with the pipette into the crucible, and the jar is then opened at leisure. If one is reasonably careful, this procedure may be further simplified by closing the jar prior to the introduction of the P, removing the rubber stopper, and transferring the P with thumb forceps directly from the water to the dry crucible in the jar; after which the stopper is immediately reinserted. To open the jar when charged in this manner, the stopper should be removed and the crucible immediately flooded with water. On ignition the P melts, assuming a plane posi-

tion; not infrequently there is sufficient water of condensation to prevent reignition when diffusion or leak occurs. It is essential that the combustion chamber be designed to prevent this. The sand and screen construction satisfactorily solve this problem. Following the combustion of the P, white trioxide is deposited on the plates and tubes, on account of which it may be advisable (not imperative) to use rubber gloves while unloading the jar. This trioxide, which is not injurious to bacterial growth, is readily removed from the glassware with a soft cloth.

This method has the following advantages: (1) Combustion is under control at all times, and the oxygen tension can be regulated. (2) A high degree of safety, simplicity, and economy is afforded. (3) Anaerobic integrity is assured at all times. (4) Atmospheric pressure within the jar precludes its collapse and difficulty in removing the cover. (5) The organisms grow under normal pressure. (6) Standard methods of isolation and cultivation are used.

Summary. A new anaerobic modification of high efficiency, complete safety, and marked economy, has been described. This method, completely elastic, may be adapted to almost any situation demanding anaerobic conditions. With it no more technical skill is required for the cultivation of anaerobes than of ordinary bacteria. With this method the authors have isolated twenty-two strains of fusiform bacilli.[2]

[2] Belding and Belding: Preliminary report on the oral flora: *J. Amer. Den. Assoc.*, 1934, *21*, 1222; July.

A METHOD FOR THE SEPARATION OF ENAMEL, DENTIN, AND CEMENTUM[1]

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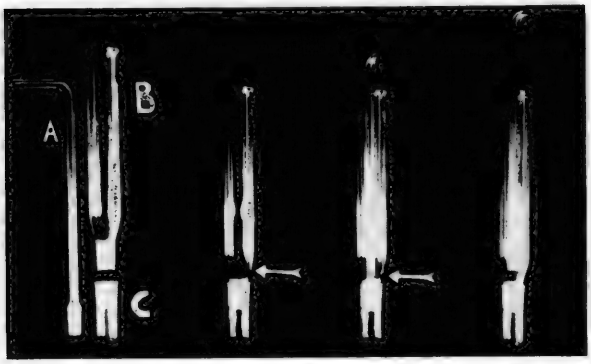
Routine analysis of enamel and dentin requires a simple method for the separation of these substances from each other and from cementum. Procedures commonly employed for the preparation of enamel, most of which utilize mechanical forces—grinding or desiccation, or combinations of these—usually give low yields, and the purity of the product is questionable. Rosebury, in connection with his study of the protein of enamel, indicated difficulties with available methods, and pointed out extreme precautions necessary to obtain a pure product.[2] Our method takes advantage of the differences in the specific gravity of enamel and dentin. Finely pulverized whole-tooth is suspended in a liquid having a specific gravity intermediate between the two materials, causing the heavier enamel to sink and the lighter dentin (and cementum) to float on the surface. The specific gravity of dentin is 2.2–2.3; that of enamel, 2.7–2.8. In order to make the conditions optimal for the preparation of a pure-enamel fraction, even at the sacrifice of a small amount of this material in the dentin fraction, we employ a liquid having a density nearer that of enamel; namely, 2.53 at 25°C.

Technique. U.S.P. IX bromoform is washed four times, or until the washings are free from acid and bromide, and dried by triple filtration through dry paper. The product, stored in the dark, is not used without repurification after it is one week old. Of the purified bromoform, 50 cc. (144 gm.) mixed with 10 cc. of absolute alcohol give a liquid with the theoretical density of 2.53 at 25°C. This solution, freshly prepared each day, is protected from light. To separate the enamel and dentin fractions, we use a specially designed funnel (*fig. 1, a*), consisting of three parts—

[1] Presented at the twelfth general meeting of the International Association for Dental Research, Chicago, Mar. 17 and 18, 1934; *J. Den. Res.*, 1934, *14*, 174.

[2] Rosebury: *J. Den. Res.*, 1931, *10*, 192.



a b c d

Fig. 1. Separatory funnel as seen in different stages of enamel and dentin separation-process ($\times \frac{1}{4}$)

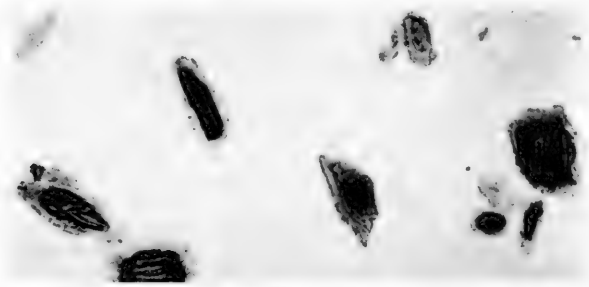


Fig. 2. Enamel cracked from tooth. Portion of each particle out of focus.

Fig. 3. Another sample of mechanically prepared enamel. Dark area probably stain lodged in crevices.

Fig. 4. Powdered whole-tooth, or mixture of enamel and dentin. Enamel and dentin easily distinguished.

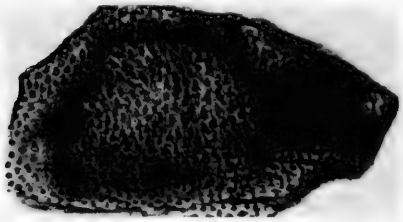


FIG. 5

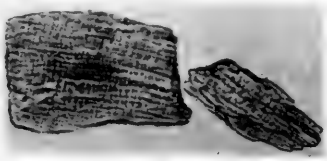


FIG. 6

Fig. 5. Mechanically prepared dentin. Dentinal tubules clearly shown.
Fig 6. Separated enamel as obtained in described process.

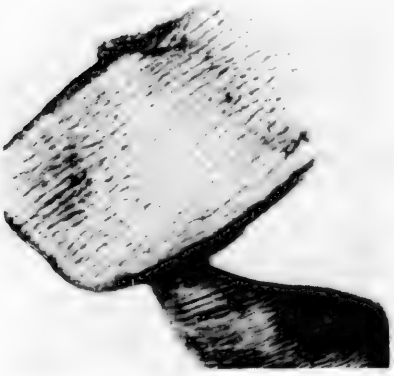


FIG. 7

FIG. 8

Fig. 7. Separated dentin as obtained in described process.
Fig. 8. Material that floated from pure enamel; possibly, in part, Nasmyth membrane.

A, B and C— which can be connected by ground-glass joints. Parts B and C are joined, filled with the mixture of bromoform and alcohol to the point indicated by the arrow (*fig. 1, b*), and Part A is gently fitted into position (*fig. 1, c*).

The sample for separation has been previously prepared in the following manner: The whole tooth is cracked to bits, the pulp removed, and the pieces extracted with a mixture of alcohol and ether to remove fat and water. The residue from the extraction, after drying at 60°, is pulverized until all passes a 100-mesh sieve. This powdered whole-tooth is then transferred to the upper chamber of the apparatus, and thoroughly mixed with the liquid, about 10 cc. more of which is added. After the apparatus has stood for one hour in a dark box, the enamel will have collected at the point indicated by the arrow; the dentin, at the top. Part A is then gently lifted about 0.5 inch and suspended in this position for 15 minutes (*fig. 1, d*), allowing the enamel to fall to the bottom of Part C; Part A is returned to position. In this way the enamel fraction is isolated in Part C; the dentin fraction, in Part B. The liquid in Part C is removed with a medicine dropper, and the enamel washed several times with ether. The product is dried at 60° and carried through the entire separation process a second time, to insure removal of all dentin. We have never seen any material float in the second process except when the apparatus was charged with a very large sample.

Isolation of enamel. The following evidence shows that the product obtained is pure, and that the yield of enamel is very nearly the theoretical amount.

1. A group of sound cuspids were prepared in the manner described above. The powdered whole-teeth were thoroughly mixed to give a uniform sample. Three lots of enamel were prepared independently by the separation procedure. Each lot of enamel was analyzed, in duplicate, for Ca and P, with the results shown below:

Percentage of analytic results for enamel obtained from sound cuspids by three separate procedures

Enamel specimen	1	2	3
Calcium	34.33	34.32	34.28
	34.33	34.31	34.28
Phosphorus	17.49	17.55	17.34
	17.49	17.53	17.50

2. A quantity of dentin separated by our process—using a mixture of bromoform and alcohol of sp. gr. 2.64 at 25°C.—was mixed with bromoform, and absolute alcohol added drop by drop until a portion of the solid material remained poised in the liquid mid-way between surface and bottom. Some material, presumably cementum, remained floating on the surface. The solution, filtered free from solid, had a specific gravity of 2.24 at 25°C. Since the solid material (dentin) neither sank nor rose, but remained suspended at any point in the solution, it is apparent that the density of the dentin was 2.24 at 25°C. Another sample of dentin prepared by mechanical means was found to have a specific gravity of 2.26 at 25°C., a very good check with the value just quoted. This experiment also indicates that dentin, separated from a solution with a density as high as 2.64 at 25°C. does not deposit any additional material until the gravity of the separating solution is lowered to 2.24 at 25°C., thus demonstrating that the enamel fraction is pure, and that the dentin fraction contains only a small amount of enamel, if any.

3. *Figures 2–7* are photomicrographs (×210) of specimens mounted in celloidin and stained with iron-hematoxylin.

4. Some pieces of enamel were obtained from a third molar after several attempts, using heat and cracking as aids in the process. The dentino-enamel junctions were ground out with a bur, and all surfaces suspected of being dentin were ground away until two experienced dentists stated independently that the pieces were wholly enamel. The particles were pulverized and labelled "pure enamel." Some of this pure enamel was mixed with dentin, and the mixture separated by the floatation procedure. This separated enamel and the pure enamel were analyzed in duplicate. We expected the results to check; however, we obtained the results shown below (A and B):

Percentage analytic results for Ca and P, for enamel preparations

	A "Pure enamel"	B "Pure enamel," after separation from dentin	C "Pure enamel," separated without admixture with dentin
Calcium	34.83	36.84	36.75
	34.83	36.95	36.75
Average	*34.83*	*36.90*	*36.75*
Phosphorus	17.16	18.58	18.65
	17.16	18.58	18.56
Average	*17.16*	*18.58*	*18.60*

5. A sample of the pure enamel was carried through the enamel-separation process without admixture with dentin. The analytic results (column C in the above summary) agree very well with those for pure enamel separated from a mixture of enamel and dentin (B). In this experiment a quantity of material floated, this material evidently causing the low results obtained for pure enamel. Its removal permitted results to be obtained for Ca and P in the enamel from pure enamel alone that were as satisfactory as those for pure enamel after separation from dentin. The nature of this material that floated from pure enamel is uncertain, having been obtained in a quantity insufficient for analysis. A photomicrograph of the material, stained with iron-hematoxylin, is shown in *fig. 8*. A considerable part of the material floated in a liquid in which dentin sank, and it was partially combustible. Possibly a portion of the material was Nasmyth membrane, since the tooth had not been long erupted. The crystals at the edge of the field are probably pieces of enamel held in organic material. Whatever the nature of the material floating from the pure enamel, this experiment demonstrates that mechanically separated enamel, prepared with great care, is likely to contain contaminants, and that our procedure entirely removes them.

Separation of dentin and cementum. The dentin fraction, obtained as described above, is washed repeatedly in a small beaker and dried at 60°. To remove any enamel impurity, the sample is carried through the enamel-separation process, using a bromoform-alcohol mixture of sp. gr. 2.53 at 25°C. If a large amount of dentin is to be purified, this process should be repeated once. The dentin and cementum are separated by employing the procedure described above, using a mixture of 85 gms. of bromoform and 20 cc. of absolute alcohol —sp. gr., 2.04 at 25°C. To insure purity, the process should be carried out a second time after washing the material with ether and drying. A dentin fraction from a routine enamel separation was divided into three portions, and the cementum removed from each portion by a *single* separation process; each sample was then carried through a *second* separation process. (In additional purification processes, nothing floated and the composition of the material was not altered.) The analytic results for Ca and P are shown on page 29:

Percentage analytic results for Ca and P, for dentin subjected to single and double processes of separation

Sample	Calcium		Phosphorus	
	Single separation	Double separation	Single separation	Double separation
1	25.92	27.17	12.44	12.89
	26.32	27.08	12.41	12.99
2	26.64	27.35	12.67	12.91
	26.33	27.26	12.59	12.86
3	26.31	27.28	12.87	12.99
	26.31	27.32	12.90	13.11

CAN ACCURATE IMPRESSIONS BE OBTAINED WITH INACCURATE IMPRESSION TRAYS?

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Eighteen years ago, the author became interested in a study of the problem presented by the great number of "make-overs" of prosthetic restorations with which the dental profession has had to contend. These studies were carried forward with the coöperation of the late Dr. Louis J. Weinstein. It was found that most of the favorite impression- and cast-materials, when properly handled, were practically neutral as to expansion and contraction. It then became evident that most failures were due not to the cast materials but to the methods of securing impressions from which the casts were derived. It is axiomatic that a cast is but a reproduction of an impression, while an impression must be a detailed negative likeness of that part of the mouth it represents. Orthodontia, bridge-work, and partial dentures for upper cases require detailed negative likeness of the teeth, arch, vault, ridge, and peripheral-tissue attachments on the labial and buccal aspects of the ridge. An accurate lower impression requires a detailed negative likeness of the teeth, arch, ridge, and peripheral-tissue attachments on the buccal, labial and *lingual* aspects of the ridge. Full-denture work and many partial-denture cases require not only detailed likeness of the arch, vault, ridge and peripheral-tissue attachments on the buccal, labial, and lingual aspects of the ridge, but also the further essential condition that, *in the impression, the supporting tissues be placed and compressed in the same positions they will assume under functional use of the finished restoration.* In peripheral adaptation it is important to secure maximum retention without interference from functional muscle-movements of the lips, cheeks, throat, tongue and floor of the mouth.

From these requirements it is obvious that the impression material must possess certain definite characteristics, lack of which would mar

the production of an accurate replica. It must be soft enough to copy the finest lines of mucous membrane, and have a consistence that will yield without displacing soft tissues. It must not warp or fall away of its own weight, and should undergo the least possible degree of expansion or contraction. It should be capable of a sharp imprint, remain where placed, harden promptly, and at undercuts break with moderate force. Since an ideal impression-material must possess the quality of fluidity or molecular sluggishness, the material must be confined in a receptacle or tray to be carried to the mouth for placement over the area of which an impression is desired. Experience teaches that, within required limits, the less material used the better the impression. In a study of the various types of impression materials, it was found that they could be managed successfully only if (a) their limitations were understood, and (b) a proper tray used for the placement of the material. Without an adequate impression-tray it is impossible to take a correct impression. This cannot be overemphasized, since herein may lie the cause for most failures.

The impression trays now in use are of the standardized, stock variety. These are usually made of aluminum or one of its alloys, brass, victoria metal, German silver, cast tin, tin plate, or Babbit metal. We have learned through sad experience that the mouth cannot be standardized to fit the limitations of such standardized trays. Non-adaptable stock impression-trays have no more scientific justification than would stock dentures. There can be no such thing as "ready-to-wear" dentures. The highly individual characteristics of the mouth make it mandatory that every appliance be made to order. Therefore, it follows that each appliance should be developed from a tray that likewise can be made to order through ready adaptation. It is surprising to find that very little study has been devoted to this fundamental element in our restorative service. While much progress has been achieved in other branches of our profession, we are still using the crude, unscientific, metal impression-trays devised in the pioneering days of our profession. The author has devoted much time and thought to this problem. His studies have resulted in the very definite conviction that metal has no place in the construction of impression trays.

About three years ago, while engaged in further research on a suit-

able substitute for the metal tray, the author received a call from Dr. William E. Cummer, suggesting a visit to his office where a product of unusual significance was about to be demonstrated. It proved to be a new type of impression-tray unlike anything either Dr. Cummer or the author had seen before. It was constructed upon a new principle from a new type of material. The tray, brought to Dr. Cummer's attention by Prof. Gies, was the product of four years of intensive experimentation by Mr. Louis Kalvin, of New York. Dr. Cummer, convinced that Mr. Kalvin's tray was an important contribution to dentistry, suggested that the author submit the new tray to rigid practical tests. For the past two years this tray has been subjected to every possible practical test by experienced practitioners and dental students. Since the results have exceeded the most sanguine expectations, the author feels it his duty to bring the findings to the attention of the profession.

The material from which this tray is fabricated is composed of a series of superimposed layers of cloth treated with a starchy substance and water-proofed. The tray is constructed in a special die, and stiffened by application of heat. The tray was subjected to the following analyses: (1) Is it easily convertible to the individual needs of every case, to insure an ideal impression? (2) Does it withstand the chemical and physical changes that take place in the setting or hardening of impression materials? (3) Is it readily adaptable to special impression-technics? (4) Does it possess requisite rigidity, and is it moisture-proof? (5) Can it be rendered sterile? (6) Is it neat and pleasing to the eye? (7) Is it inexpensive, so that a new tray can be used for each patient? The tray successfully met all these requirements. The tray not only introduces more precision in the taking of impressions, but also provides the further advantage of a *precise* means for the *removal* of plaster impressions. By present methods, it is impossible to foretell how (or in how many parts) an impression will fracture in the course of its removal. The new tray introduces *certainty* where now there is *uncertainty*. This is accomplished by the design of the tray. Its unique features are the fracture lines which can be *predetermined*, thus giving the operator complete control over the sectional removal of the impression both as to number and location of the fractures. This is a genuine advance in the direction

of precision that will be much appreciated by both dentist and patient, because it reduces the need for re-taking impressions and insures a more perfect fit for the appliance. The following description of the technic for the use of the tray in an *upper case*, with plaster-of-paris as the impression medium, illustrates the tray's adaptability.

A tray of proper size is selected; if desired, universal handle is attached (*fig. 1*). Tray is fitted to mouth and impingements noted. Flanges are then trimmed with shears for height and length, to conform to individual characteristics; palate also is trimmed for length. In very high vault it is desirable to add strip of compound, or wax, across posterior border of palate so that plaster, while plastic, will there make proper contact. While fitting tray to mouth, mark with pencil approximate position of desired fracture lines (*fig. 2, A*). Remove tray and with sharp instrument slit tray where marked (*fig. 2, B*). Fill tray with impression plaster and seat to place in mouth. When plaster starts to set, but while still mushy, insert *Kalvin Channel Loop* (*fig. 2, C*) to proper depth into each slot previously cut in tray; and work Channel Loop up and down to form definite groove in plaster, to facilitate separation of impression into predetermined segments along definite parting lines (*fig. 3*). Remove tray when plaster has set. With blunt instrument wedge into grooves, and remove sections of impression. Place sections in suitable receptacle or replace in tray. Assemble sections either in or out of tray, and proceed in usual manner (*fig. 5*). The same procedure is followed for ***lower impression*** with exception that, having lingual flange, lower tray must be trimmed to conform to individual characteristics of labial, buccal and lingual aspects of mandible. For predetermined fracture-lines, proceed as above. Method is also adaptable for sectional compound-impressions, or combination sectional compound- and plaster-impressions.

For *upper case* select tray of proper size; attach handle if desired (*fig. 1*). Trim labial and buccal flanges where desired for separate sections (*fig. 4*); trim palate for length. Heat impression compound in flame, and trace to floor of tray. Heat roll of compound to proper consistency in water-bath, and wipe one side dry. Heat dry portion in flame, and stick to compound already attached to tray. Place compound in position in tray, and shape as desired, avoiding creases. Chill floor and vault portions of tray in ice water (*fig. 6*). Gently glaze outer surface of compound and dip into warm water to temper. Carry to mouth and seat to position, instructing patient to make desired muscle movements; chill and remove. Chill again in ice water and, with sharp knife, trim away all excess compound (*fig. 7*). Wipe

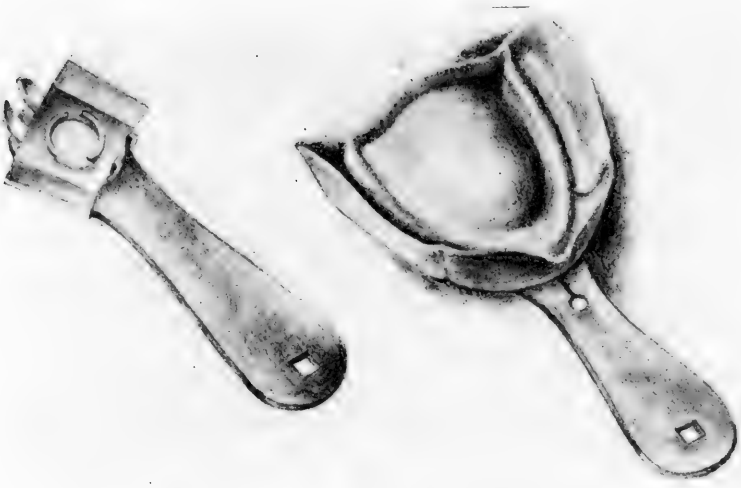

Fig. 1. Tray handle, and handle attached to tray.

Fig. 2. *A* Pencil, marking desired fracture line. *B* Instrument, shown slitting tray where marked. *C*—Insertion of Kalvin Channel Loop.

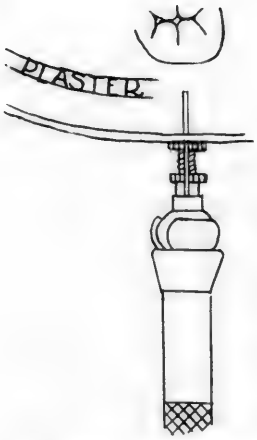

Fig. 3. Channel Loop worked up and down, to form definite grooves in plaster.

Fig. 4. Flange trimmed for separate section.

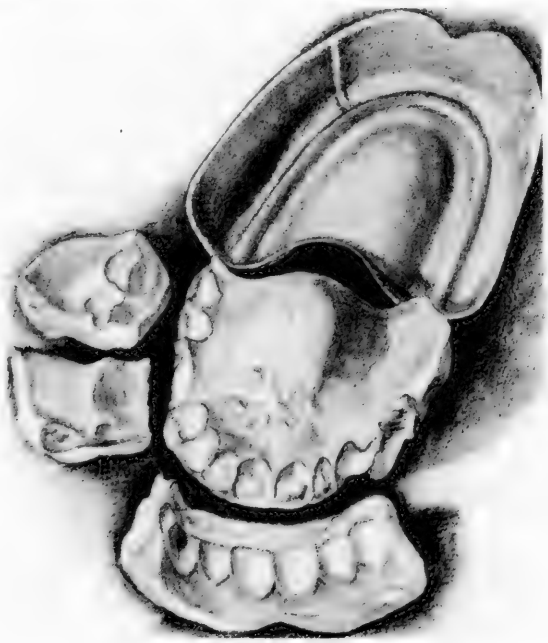

Fig. 5. Tray and assembled sections.

Fig. 6. Floor and vault portions of tray chilled in ice water.

Fig. 7. Excess of compound trimmed away.

Fig. 8. Sections assembled outside of tray.

dry, and heat vault and floor portions in flame; dip in warm water to temper; re-insert to place with gentle pressure; chill and remove. Chill again and wipe dry. Where muscle- or tissue-trimming is desired, heat that part of

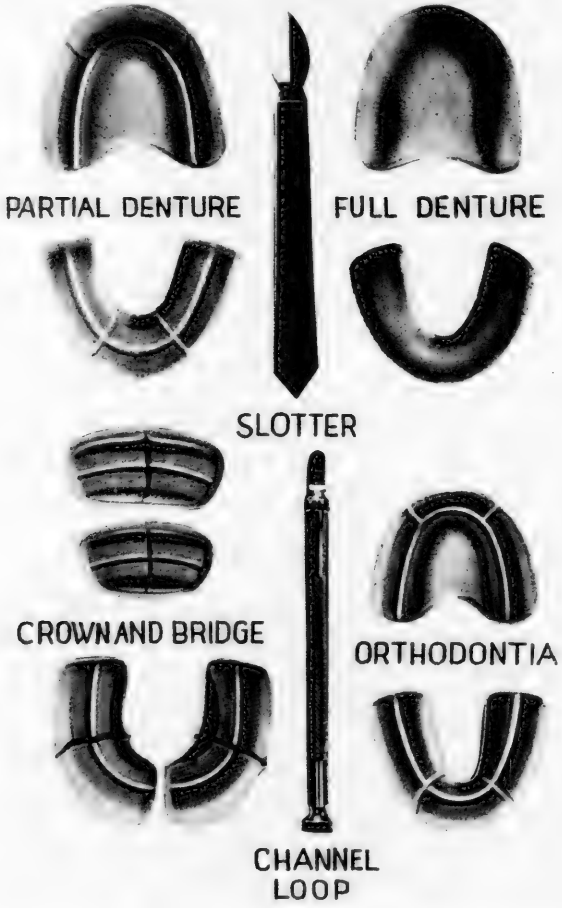

Fig. 9. Forms of tray and accessories.

impression in flame, dip in warm water to temper and place to position. Have patient exert proper muscle movements; chill and remove. Chill again in ice water and wipe dry. If necessary, repeat until muscle-trimmed

as desired. To compress saddle area or areas, heat entire surface of compound *except area or areas where compression is desired.* Dip in warm water to temper, and place to position with proper distribution of pressure; chill and remove. Chill again in ice water. Trim excess compound, and bevel edges. Notch where desired. Vaseline the beveled or notched surfaces. Place impression in mouth. Take small portion of heated compound, shape as desired, and glaze in flame. Dip in warm water, and apply to buccal and labial portions of teeth or ridge as desired. Press to place with light pressure on cheeks and lips, being sure that compound overlaps onto beveled or notched portion of impression already in position in mouth; chill and remove. Chill all in ice water. Wipe dry and assemble sections (*fig. 8*). Some operators prefer to make basic impression in compound, using plaster for buccal and labial sections.

The best denture-work is obviously Nature's own. This indisputable fact is the foundation for the program of prevention as the ideal toward which our profession must continue to strive. While future generations are bound to benefit from increased knowledge of preventive measures, the present generation is entitled to the best service our profession can render by way of providing efficient artificial substitutes. A comfortable, well-fitting appliance is the right of every person whose teeth have been destroyed. A properly fitted appliance can be constructed only from an accurate impression, and an accurate impression depends on a properly fitted tray. The importance of the impression tray has been overlooked; it is the "forgotten man" of our profession. Both the public and the dentist suffer the consequences. Our experiments of the past two years justify the belief that a "new deal," based upon newly discovered principles, is at hand. It will enable us to introduce more scientific methods at the inception of appliance construction. This brings progress where it is urgently needed. Such progress cannot fail to yield more satisfaction to the dentist, and greater comfort and better health to the patient.

SELF-PROTECTING MECHANISM OF THE MOUTH AGAINST ENDOGENOUS BACTERIAL FLORA, AND MOVEMENTS OF EXTRINSIC ORGANISMS WITHIN THE ORAL CAVITY

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Management of infections of the mouth has been based upon clinical observation and empirical therapy. This method of treatment is superficial because of general lack of knowledge of the oral flora, except perhaps as a smear may present a cross-section. The experiments described below show that a complex but remarkably efficient self-protective mechanism is constantly operative within the oral cavity. In these investigations we sought to learn whether normal oral mucous membrane has the power of auto-disinfection that is constantly operative in normal skin. This paper includes our experimental findings, and also describes a few infections illustrating the mechanism we have observed.

Thomson and Thomson (12) stated: "It seems to us that the normal flora of the mouth are of no value whatsoever in human economy, except that perhaps their presence on the mucous membrane may prevent the settling down of other more dangerous bacteria. They may also serve as a constant stimulus for the production of antibodies. We believe that if the mouth could be kept sterile our health would be greatly benefitted." Allen (1) emphasized the difficulties of securing a normal mouth for study, and called attention to the fact that in the oral cavity of most individuals there are one or more areas of infection. He did, however, find the following bacteria in the "most normal" of the oral cavities: Staph. albus, Staph. aureus, Str. hemolyticus (seldom), M. catarrhalis, various small micrococci both gram-positive and gram-negative, vibrios, spirilla, spirochete, fusiform bacillus, B. necrodentalis, B. buccalis maximum, Cladothrix buccalis, B. proteus, B. mesentericus, B. subtilis,

B. fluorescens, sarcinae, yeast, molds. Edington (5) stated that "the nasopharyngeal and mouth varieties of organisms are much the same as the nasal and are derived from the food we eat, the water we drink, and the air we breathe." Thomson and Thomson (12) challenged this statement because the bacteria in food, water, and air are very different from those in the mouth. These authors concluded that the flora of the mouth is intrinsic and characteristic of this cavity; is to a great extent unaffected by air, food, or water; and is derived from previous human contacts and possibly from certain animals. Brailovsky-Lounkevitch (4) found that, on cheeks and palate, small gram-positive diplococci predominate in smears, together with a few leptothrix and spirilla. On the tongue the same diplococci occur in greater numbers, in addition to masses of staphylococci, short and long thin-rods, spirochetes, leptothrix filaments, and vibrios. Organisms are found in greater abundance among the villi on the back of the tongue than on its tip.

Podbielsky (10) and Jeannin (8) observed that immediately after birth the mouth is sterile and remains so until about the sixth hour, when there is begun a gradual increase in concentration of bacterial population until the flora becomes established and remains one of the densest aggregations in the body for the remainder of life. The order in which various strains of bacteria invade and adapt themselves within the mouth are: staphylococci, B. coli, and Staph. parvulus. Later there appear enterococci, Str. salivarus, M. candicans, and various sarcinae. Cultural methods have demonstrated B. coli, B. lactis aerogenes, Staph. albus; also small cocci, bacilli, together with (in a few cases) pneumococcus, B. bifidus, and Staph. parvulus by the second day, owing in part to ingestion of food. At a later date streptococci, staphylococci, and coliform organisms predominate, when cultural methods are used for identification. The endogenous flora of the adult is much the same as that of the child after dentition, but the varieties are more numerous according to the state of the mouth and the condition of the teeth.

Bloomfield (3) found that the most common organisms on the tongue were gram-negative cocci. Non-hemolytic streptococci were constantly present; less frequently, diphtheroids. Hemolytic influenza bacilli, hemolytic streptococci, and Staph. albus were present

only as transients. In experiments on filtered, germ-free saliva, Florain and Sanarelli (6) found saliva not only a poor culture medium, but also slightly inhibitory to growth of bacteria. We have obtained similar results. Goodby (7) suggested that the mouth cleanses itself in two ways: (a) by shedding epithelial cells—"a film taken from the buccal mucous membrane and stained with Leischman's stain will show a group of epithelial cells which have become detached and are surrounded by a number of bacteria;" (b) by mechanical movements

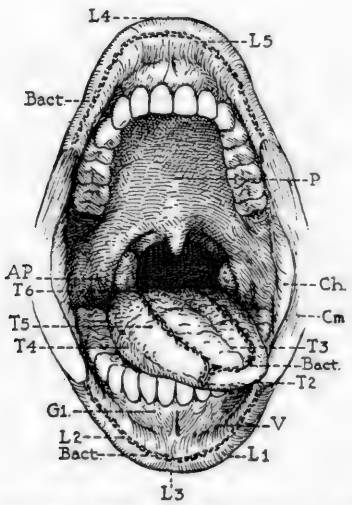

Fig. 1. Drawing showing oral areas subjected to study. (See summary of abbreviations, page 44. The following abbreviations there have no corresponding indications here: S, skin surface below L_1. G_2, lingual surface of lower gums. T_1, frenulum of tongue.)

of tongue and cheeks, which excite salivary secretions and carry out bacteria. Kuster (9) doubted that saliva had antiseptic value, and challenged the oft-repeated statement to this effect concerning the dog, explaining that, in licking a wound, a dog produces counter-irritation and mechanical cleansing of the area. He further stated that more wounds on legs of dogs prove fatal than has been believed.

Arnold and associates (2) have shown that skin possesses self-disinfective power, and have studied most exposed surfaces of the body. In research in this laboratory on a problem of economical

and practical methods of sterilizing clinical thermometers for hospital practice, Miller and Ryan (11) found that, after a thermometer had been removed from a mouth and rolled over the surface of agar plates, there were small white colonies in a narrow band 2–3 mm. wide along the path of the thermometer, close to its protruding free-end. This zone was found to correspond to the place where the lips had been in contact with the glass of the thermometer. In many instances the only bacteria on the agar surface were confined to this narrow continuous band of colonies. These observations led us to include the lip region in this study.

Experiments. Preliminary studies indicated that definite *anatomical regions* must be chosen, and the bacterial flora of these areas studied by removing cultures at frequent intervals. The selected areas are listed below, and also shown in *fig. 1*; in the text the following abbreviations are used for convenience:

AP—anterior pillar. *Ch*—mucous surface of cheek. *Cm*—corner of mouth. *G1*—labial surface of lower gums. *G2*—lingual surface of lower gums. *L1*—junction of skin and mucous membrane of lower lip. *L2*—moist region of lower lip which meets upper lip. *L3*—midline of lips. *L4*—junction of mucous membrane and skin of upper lip. *L5*—moist region of upper lip which meets lower lip. *P*—hard palate. *S*—skin surface immediately below junction of skin and mucous membrane of lower lip. *T1*—frenulum of tongue. *T2*—tip of tongue. *T3*—midline of tongue. *T4*—side of tongue. *T5*—dorsum of tongue. *T6*—base of tongue. *V*—vestibule of mouth.

The endogenous flora of these regions were studied by culturing the areas on plain-agar plates, with cotton swabs moistened in normal saline solution. Quantitative bacterial-counts were not carried out, for we sought only to ascertain the relative density of the bacterial population on these surfaces. The relative abundance and types of flora in these regions are indicated below:

Region	*Colonies no.*	*Types of colonies*[1]
S	1220	Staph. and a few odd colonies
L1	170	Staph. (160) and a few colorless colonies
L2	2100	Staph. (about 200) and mucoid colonies
L3	3000	Staph. (about 100) and mucoid colonies
L4	79	Staph. and few colorless colonies

[1] The numbers of staphylococcus colonies decreased as examinations of the field progressed backward toward the pharynx.

L5	V.h.g.[2]	Staph. (75–100) and mucoid colonies
Cm	4–5000	Staph. (150 to 1000) and many medium-sized colonies, colorless, mucoid
V	1200	Staph. (about 75) and mucoid colonies
G1	1000	Staph. (about 60) and mucoid colonies
G2	6000	Staph. (20–30) and mucoid colonies
T1		Sterile, excepting a few pin-point colonies
T2	11,000	Staph. (about 1000) and mucoid colonies
T3	10,000	Staph. (about 1000) and mucoid colonies
T4	V.h.g.	Staph. (few); fine mucoid colonies and gram-neg. cocci present
T5	V.h.g.	Staph. (few); fine mucoid colonies and gram-neg. cocci present
T6	V.h.g.	Staph. (few); fine mucoid colonies and gram-neg. cocci present
Ch	V.h.g.	Staph. (few); fine mucoid colonies and gram-neg. cocci present
AP	V.h.g.	Staph. (few); fine mucoid colonies and gram-neg. cocci present
P	V.h.g.	Staph. (few); fine mucoid colonies and gram-neg. cocci present

The order of predominance among the staphylococci seemed to be: aureus, citreus, and albus. Several days' incubation was required to obtain good color. The colorless colonies, taken by swabs from the mouth were generally larger than those from the lips, and for the most part were distinctly gram-negative cocci; those from the lips seemed to be in a transitional state of dissociation (by stain). About 300 agar plates were used in this series; the numerals indicate averages. Blood-agar plates showed hemolytic staphylococci and streptococci on regions *Cm*, *L3*, and *T2*.

The next experiment was an attempt to determine relative numbers of bacteria on the tongue by scraping with a sterile knife, and then diluting in 100 cc. of normal saline the material picked up by swabs, by shaking the cotton from the applicator into the solution. Bacterial counts were made upon this material by the usual dilution method. One side of the dorsum of the tongue was scraped; the other was used as control. (*a*) With the right side scraped, swabs were made at three-minute intervals; the tongue was held away from the other portions of the mouth to avoid contamination and mechanical movements. The results are shown in *table 1, A*. (*b*) Experiment (a) was repeated, but the left side was scraped, and the right used for control. The results are shown in *table 1, B*. Although the results are extremely variable, there seems to be an inexhaustible supply of bacteria on the dorsum of the tongue.

To determine the rate at which bacteria spread from lips into

[2] Abbreviation for "very heavy growth."

mouth, and if possible the routes they take toward the throat, we proceeded as follows: An agar-plate growth of B. prodigiosus, washed off with 10 cc. of normal saline solution, was diluted to 1:100,000. A sterile swab saturated in this solution was applied over various portions of the mouth, at five-minute intervals, for thirty minutes. Plates were seeded by swabs taken from other oral areas. (*a*) A suspension of B. prodigiosus, as described above, was swabbed in the angles of the mouth, and plates were seeded from areas *L1*, *T2*, and *T5*. *Table 3*, *A*, gives the average results. Plates seeded from other areas of the mouth showed, at the end of thirty minutes, 1980 colonies at the angle of the mouth, 1 colony each from upper lip (which had come in contact with lower lip, side of tongue, buccal surface of cheek, and hard palate), and 19 colonies from base of tongue. (*b*) Suspension of B. prodigiosus was swabbed over the junction of mucous membrane and skin of the lower lip. In thirty minutes, the area originally seeded showed 9 colonies; zone on lips, where upper touches lower, 14 colonies. Cultures from other oral areas were negative. (*c*) B. prodigiosus suspension was swabbed on the zone of contact of the lips with results shown in *table 3*, *B*. (*d*) Suspension of B. prodigiosus was placed on the dorsum of the tongue, and normal oral movements carried on, with results shown in *table 3*, *C*. (*e*) When suspension of B. prodigiosus was swabbed on the tip of the tongue, and normal oral movements carried on, the results in *table 3*, *D*, were obtained. The labial surface of lower gums showed 1 colony; tip of tongue 108; midline of tongue, 14; dorsum of tongue, 14; hard palate, 6; all other areas were negative. (*f*) Suspension of B. prodigiosus was swabbed on the base of the tongue, and plates seeded by swabs from other oral areas, with results shown in *table 3*, *E*. There were 2 colonies on plates seeded from mucous surface of cheek; 15, from hard palate; base of tongue showed very heavy growth; all other regions were negative. (*g*) Up to this time we had observed that the frenulum of the tongue was relatively sterile at all times, even for normal oral flora. This area was next seeded by swabbing-on suspension of B. prodigiosus. Plates were seeded by means of swabs from this region, at five-minute intervals, with results shown in *table 3*, *F*. After 30 minutes, there was growth of 5 colonies for region T4; 29 for region T5. The foregoing results, reviewed collectively, demon-

strated that B. prodigiosus did not disappear from corners of mouth, midline of lips, and base of tongue as quickly as from other portions of the oral mucosa.

In the next experiments we endeavored to learn how long exogenous bacteria would remain upon these areas. The same technic was used, as before, but the periods of observation were extended to 30, 50, and 90 minutes. All oral regions were tested. We found no disappearance of these foreign bacteria from dorsum and base of tongue, and hard palate; but, seeded on the other regions, they disappeared within these periods. The midline of the lips (L3) was seeded with suspension of B. prodigiosus, and the tongue kept as nearly motionless as possible. Swabs from tip of tongue were obtained at five-minute intervals; from other areas, in 30 minutes. These were inoculated in the usual manner on agar surfaces. The regions seeded showed heavy growth of B. prodigiosus; 59 colonies were grown from vestibule of mouth; 15 from labial surface of lower gums; all other areas were negative. These results indicate that mechanical movement of the tongue is a decisive factor in the spread of bacteria from the labial region over the oral mucosa. The tip of tongue was seeded with suspension of B. prodigiosus. Swabs were taken and plates inoculated from all regions of the mouth after 5 minutes; but this time the tongue was allowed to assume, as nearly as possible, its normal movements. Contamination or spread was shown for the following regions (the numerals indicate number of colonies): *Cm*, 22; *L2*, 42; *V*, 1; *G2*, 3; *L5*, 37; *T4*, 17; *Ch*, 2; *Ap*, 0; *T6*, 2100; *P*, 35; *L3*, *T2*, *T3* and *T5*—heavy growth; *L1*, *S*, and *T1*—negative.

The self-sterilizing properties of gums near the alveolar crest were investigated. A double-end saliva ejector was applied on each side of the alveolar ridge to eliminate mechanical removal of organisms by flowing saliva, and the mouth held as nearly quiet as possible. B. prodigiosus, in normal saline solution (1:100,000), was applied to gums around teeth; swabs were taken from different but adjoining areas at five-minute intervals and smeared over the surface of an agar plate. A control plate was seeded from the suspension. The average results are given in *table 2, A*. Similar findings were obtained for the surfaces of the teeth. The results indicate that there is no self-sterilizing power of gums or surfaces of teeth, even when the tissues

appear to be normal. The experiment was repeated and the mouth allowed to assume normal, or slightly exaggerated movements; but our findings varied so much that we are unable to give a definite

TABLE 1

Relative numbers of bacteria on tongue

A. Right side of dorsum scraped; *left side used as control*

	BEFORE SCRAPING	IMMEDIATELY AFTER	AFTER 3 MIN.	AFTER 6 MIN.	AFTER 9 MIN.	AFTER 12 MIN.	AFTER 15 MIN.
Right side	1,600,000	300,000	300,000	200,000	700,000	400,000	2,700,000
Left side	1,700,000	3,300,000	300,000	3,400,000	4,000,000	200,000	2,100,000

B. Left side of dorsum scraped; *right side used as control*

Left side	8,500,000	100,000	3,500,000	1,800,000	2,500,000	500,000	200,000
Right side	4,000,000	2,400,000	1,700,000	1,600,000	500,000	100,000	300,000

TABLE 2

Tests of self-sterilizing properties: B. prodigiosus, in terms of average number of colonies on seeded plates

A. Bacteria applied to gums around teeth

REGION	5 MIN.	10 MIN.	15 MIN.	20 MIN.	25 MIN.	30 MIN.	35 MIN.	40 MIN.
Gingiva, 1	86	93	91	68	81	79	90	82
Gingiva, 2	127	123	131	134	122	108	141	138
Gingiva, 3	209	184	197	188	200	192	204	199
Control	350							350

B. Side of tongue (T4)

Side of tongue, 1	66	52	40	34	21	17	9	2
Side of tongue, 2	246	228	193	173	154	122	89	56
Control	313							326

C. Mucosal surface of cheek (Ch)

Mucosal surface of cheek, 1	164	133	108	92	51	27	11	1
Mucosal surface of cheek, 2	138	131	111	68	72	43	29	9
Control	414							410

group of figures. It was evident, however, that surfaces of gums that may be rapidly bathed by saliva, and those reached by movements of cheeks and tongue, showed marked decrease in numbers of plated

TABLE 3

Rate at which bacteria (B. prodigiosus) spread from lips into mouth (in terms of average number of colonies on seeded plates)

A. From angles of mouth

REGION*	IMMEDIATELY	5 MIN.	10 MIN.	15 MIN.	20 MIN.	25 MIN.	30 MIN.
L1	0	0	0	0	0	0	0
T2	26	11	1	0	0	1	1
T5	44	12	5	4	0	1	1

B. From zone of contact of lips

L1	0	0	0	0	0	0	0
L3	0	8	1	0	1	0	1
V	0	2	16	0	0	0	0
G2	0	35	16	3	3	0	0
T2	0	Heavy	Heavy	250	70	41	12
T3	0	500	400	125	65	34	16
T4	0	500	220	159	170	150	46
T6	0	Very heavy	Heavy	Heavy	Heavy	200	150
P	0	400	200	65	31	30	20

C. From dorsum of tongue; normal movements of mouth

L1	0	0	0	0	0	0	0
Cm	0	0	0	0	0	0	0
T2	360	22	20	3	0	0	0
T6	936	240	86	59	129	71	35

D. From tip of tongue; normal movements of mouth

Cm	0	48	7	3	0	0	0
L3	0	1380	214	40	3	0	0
T4	0	229	93	34	3	4	1
Ch	0	780	720	300	282	131	125

E. From base of tongue

Cm					No growth		
L3					No growth		
T2					No growth		
T3	0	29	10	7	5	3	0
T4	0	0	1	1	1	2	1
T5	0	10	47	13	10	9	2

F. From frenulum of tongue

L1	0	0	0	0	0	0	0
Cm	0	0	0	0	0	0	0
T2	0	1242	40	15	1	0	0
T6	0	1064	510	443	360	193	73

* See abbreviations, page 44.

bacteria; but interspaces between teeth held their relative numbers of organisms in place, probably because of lack of mechanical friction.

Area T4 was then examined, by the technique in the experiment on gums. The double saliva-ejector was also used, and the mouth held in a position as nearly fixed as possible. A control plate was seeded from suspension of B. prodigiosus. *Table 2, B*, presents the average data, which show that the mucosa of side of tongue, like normal skin, is capable of destroying bacteria. Area Ch was examined, using the same technic as that for T4, with results shown in *table 2, C*. A control plate was seeded from suspension of B. prodigiosus. Here too the mucosa destroyed bacteria without aid of mechanical movements or flow of saliva.

An attempt was next made to plate longitudinal zones on the dorsum of the tongue as affecting transient bacteria. This surface was divided into three zones, of almost equal width, from the midline of tongue to junction of dorsum and lateral surface. Suspension of B. prodigiosus (normal saline, 1:100,000) was placed upon the lips, and normal movements of licking lips and opening and closing mouth were carried out. These zones were swabbed and plated. Here too the numbers of prodigiosus organisms on the plate, by colony count, were by no means constant; but the longitudinal zone that seems to serve as the most active highway for transient organisms was the middle third of each dorso-lateral surface. This zoning of transient organisms seemed to be related to number of times, and firmness with which, tongue was pressed against roof of mouth. It was also noted that movement of bacteria in a backward direction was very rapid —in one observation it occurred in two minutes after licking lips to swabbing organisms from base of tongue, even though as little sucking action as possible was induced.

Discussion. The bacterial flora of the mouth may be divided into intrinsic or endogenous, and transient or exogenous, groups. The former consists of strains of organisms that inhabit the normal mouth; the latter, of foreign bacteria that are more or less transient contaminants, such as those introduced by air, food, and water. There are other means of contamination, as by introduction of foreign bodies into the mouth and also by licking the lips. Lips, gums, and tongue seem to have an inexhaustible supply of bacteria, both in numbers and strains. There is little if any spread of transient bacteria from lips, gums and tongue when mouth is held in an almost fixed position;

but with mechanical movements of cheeks and tongue, these organisms rapidly travel, primarily backward toward throat and pharynx. Movement of bacteria forward from throat is rare and improbable, except after coughing and expelling secretions in this manner. Bacteria that reach tip of tongue seem to use the mid-portion of each dorso-lateral surface as their highway of travel backward.

As has been found for normal skin, oral mucosa—except dorsum of tongue, gums, and zone of contact of lips—has power of destroying bacteria. Mechanical oral movements and flow of saliva, together with expectoration and swallowing, are other means of cleansing the oral cavity. Exfoliation of epithelial cells, whereby organisms are apparently destroyed, is a third method of oral cleansing; but saliva itself is not a germicide.

We conclude from our experiments that, if infectious oral diseases are to be successfully managed, we must deal with bacteria that normally inhabit the mouth as well as with transient pathogenic organisms. There is apparently one primary area of seeding—zone of contact of lips—capable of transmitting pathogenic organisms even though no gross evidence of infection may be seen. Gums may also be a seeding zone, which frequently presents symptoms of infectious processes. These seeding areas, rather than pharynx and throat, should be considered as the origin of mouth infections.

From a clinical standpoint, acute diffuse infections of mouth and throat may readily be seeded from the non-sterilizing zone of contact of lips, whether mucosa presents symptoms or not. An attempt should be made, therefore, to inhibit growth of pathogenic organisms on lips, while directing treatment to areas of definite infection. Moeller's glossitis—exfoliation of epithelial cells of tongue—is a rare disease; but a condition typical of it is a bright red line running over the side of the tip and then bifurcating, to extend backward along the middle of each dorso-lateral half toward the base. This has been observed primarily in patients suffering from a debilitating condition, such as anemia.

We have shown that gums have no power of auto-sterilization. It is little wonder, therefore, that gingivae are frequently infected. Constitutional diseases have unknown influences upon alveolus and gums, which materially increase the possibilities of infection of these

tissues by bacteria constantly present on them. This may be observed in the gingivites, in blood discrasias, in diabetic patients suffering from chronic gastro-intestinal conditions, and in general constitutional infections.

When gums harbor pathogenic organisms, and tongue or cheek is permitted to remain fixed against them, the auto-sterilizing power of mucosa covering cheek is neutralized and these contiguous tissues become sites of infection. Mechanical movements and frequent irrigations are the best means of cleansing the mouth. Ulcerative stomatitis is, therefore, an infection that may invade cheek and tongue from gums, as a seeding zone, even though gums may not present definite symptoms of ulceration.

Our results show that cheeks, side of tongue, frenulum of tongue, and vestibule of mouth, have auto-sterilizing power, and do not become sites of infection until this power is broken down by trauma, contact infection, or constitutional disease. Aphthous stomatitis and stomatitis herpetica (canker sore), with their lesions definitely located over these surfaces, are oral conditions based upon systemic pathology and cannot be permanently cured by local treatment.

Conclusion. The zone of contact of lips, and the gums, are seeding areas for oral infections, and have no power of auto-sterilization. Oral infections tend to pass backward toward pharynx and throat, instead of forward therefrom. Lips are sources of supply for acute diffuse infections of the oral cavity. Gums are the seeding areas for infections of contiguous tissues of tongue and cheeks. Infections over other mucous surfaces, more chronic in character, may be considered to be on a constitutional basis.

REFERENCES TO LITERATURE

(1) ALLEN, R. W.: Bacterial diseases of respiration and vaccines in their treatment; Lewis, London (1913).

(2) ARNOLD, L., AND SINGER, C.: Auto-disinfecting power of the human skin, *Proc. Soc. Exp. Biol. and Med.*, 27: 367 (1930). ————, AND KARNS, R.: Optimum bacterial suspension for testing skin disinfection, *Ibid.*, 28: 375 (1931). ————, GUSTAFSON, C., HULL, T., MONTGOMERY, B., AND SINGER, C.: The self-disinfecting power of the skin as a defence against microbic invasion *Amer. Jour. Hyg.*, 11: 345 (1930). MONTGOMERY, B. E.: Influence of broth cultures and media upon the self-disinfection of the skin, *Proc. Soc. Exp. Biol. and Med.*, 28: 374 (1931). ————, AND FISHER, V.: Variations in the self-disinfecting power of the skin during the menstrual cycle, *Ibid.*, 28: 952

(1931). MONTGOMERY, B. E., AND BART, A.: The self-disinfecting power of the skin, *Amer. Jour. of Hyg.*, 19: 217 (1934).

(3) BLOOMFIELD, A. L.: The fate of bacteria introduced into the upper air passages. II. B. coli and Staphylococcus albus, *Amer. Rev. Tuberculosis*, 3: 553 (1919–20)

(4) BRAILOVSKY-LOUNKEVITCH, Z. A.: The normal flora of the mouth. (Contribution a l'etude de la flore microbienne habituelle de la bouche normal: Nouveaunes enfants, adultes). *Ann. de l'Instit. Pasteur*, 29: 379 (1915).

(5) EDINGTON, D. C.: Streptococcal infection by the nasal and buccal paths. *Brit. Med. Jour.*, 1: 304 (1922).

(6) FLORAIN AND SANARELLI [quoted by Kuster (1913)]. No reference given. (See 12.)

(7) GOODBY, K. W.: Diseases of the gums and oral mucous membrane, pp. 8 and 496; Oxford University Press (1931).

(8) JEANNIN, C.: De la flore microbienne de la bouche du nourrisson, *Obstetrique*, 9: 322 (1904).

(9) KUSTER, E.: Die Bakterien in der Gesunden Nase. Kolle u. Wassermann: Handbuch der Pathogenen Mikroorganismen, 6: 450 (1913).

(10) PODBIELSKY, A.: Untersuchung der Mikroben der Mundhoehle von Erwachsenen und Kindern im gesunden Zustand, *Central. f. Bakt.*, 9: 617 (1891).

(11) RYAN, V., AND MILLER, V.: Disinfection of clinical thermometers, *Amer. J. Nursing*, 32: 197 (1932).

(12) THOMSON, D., AND THOMSON, R.: The common cold, *Annals of Pickett-Thomson Laboratory*, 8: 57 (1932).

STUDIES OF THE pH OF NORMAL RESTING SALIVA. I. VARIATIONS WITH AGE AND SEX[1]

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I. INTRODUCTION. The reaction of saliva has been a constant source of interest since antiquity, being associated with both oral and systemic disease, and as a consequence of this interest it has been the object of many studies. Those of the ancients were merely conjectural, but interesting because of their empirical correctness in many instances. Hippocrates, 450 B.C., writing concerning colds (35), stated that "the mucous secretions are at first watery and acrid, and after improvement thicker and less acrid." On fevers (22), he wrote of the "secretions as being scanty and acrid." Paul of Aegineta, 636, wrote (34) "that the vomitus resulting from the spoiling of food in the stomach makes saliva more acid and is injurious to the teeth." Much later, with advancement of chemistry and knowledge of indicators, salivary reaction was tested with litmus, lacmoid, and turmeric. While not precise, these tests gave a fairly good indication as to whether saliva was acid, neutral, or alkaline. In the latter part of the nineteenth century, quantitative titrations were made. Having been improved, titration methods are used at present to determine "total" acidity and alkalinity of saliva. It was not until the early part of the twentieth century that studies were made of the H-ion concentration, or "actual" acidity and alkalinity, of saliva.

II. LITERATURE. Only results for H-ion concentration of *normal resting saliva* are mentioned in the following brief summary of *pH findings for saliva:*

[1] On the program of the thirteenth general meeting of the International Association for Dental Research, Chicago, March 16–17, 1935. Received for publication: August 29, 1934.

[2] Rockefeller Fellow in Dentistry.

Foa (12); electrometric method; 8.2 before meals; 8.3 after meals. Kirk (24); Hildebrand electrode; 5.6 to 8.6. Michaelis and Peckstein (33), three samples undiluted, 6.79, 6.91, and 6.92; two samples diluted with distilled water, 6.65 and 6.34; diluted with freshly boiled distilled water, 7.01. Graham (17); colorimetric method; dialyzed; in general, saliva having 6.7 or above reacted alkaline to litmus; below 6.7, acid. Bloomfield and Huck (1); colorimetric method; centrifuged; 6.0 to 7.3. Starr (41); 228 healthy normal subjects; 5.75 to 7.05; mean, 6.60. La Farga (25); after meals; 7.0 to 7.4. McClelland (27); normal, resting, 6.3 to 7.4. Bunzell (3); normal, resting, several age-groups; average, 6.00 to 6.64. McClelland (28); normal, resting; reaction varied in different subjects, and in same subjects at different times, without oral stimulants: 6.4 to 7.1. Carlson and McKinstry (5); 127 college men; 6.66 to 7.02; average, 6.85. Popper and Hoffner (38); electrometric method; healthy individuals, 6.7 to 7.52; fairly constant, same individual. McIntosh, James, and Barlow (29); indicator papers; 5.9 to 6.8. Gans (14); colorimetric method; 90 samples, some boiled and filtered; 6.4 to 7.0. Rich (39); electrometric method; 57 normal subjects; average 6.82. Clark and Carter (7); cannulated, parotid gland, 6.40; mixed, same individual, 6.52; cannulated, sublingual gland, two cases, 6.40 and 6.25; mixed, these two cases, 6.50 and 6.35. Henderson and Millet (20); normal, 6.0 to 7.4; after meal dropped to point slightly below value previous to meal; gradually rose between meals. Casaratto (6); generally acid, 5.0 to 7.0; average (100 cases), 6.35. McKeag (30); normal, 70 boys, 6.1 to 7.7. Jonoff and Tschetunoff (23); 412 boys and girls, 6.8 to 7.6. Broderick (2); 117 cases, 4.9 to 8.0. Mathur (26); normal individuals, ages 20 to 35; 6.5 to 8.0. Stern (42); colorimetric method; 100 boys and girls; average 6.82. Hanke (18); indicator papers; dietary study of children; various regions of mouth; 5.4 to 7.0; average 6.2 to 6.4. These data show, in general, that the average pH of normal resting saliva lies on the acid side of neutrality. However, several factors require more study before an average pH for *normal resting saliva* can be established for use as a standard in future investigations. These factors are age, sex, and diurnal influences. Data concerning these factors will be presented in this and a succeeding paper.

III. METHOD. The monocolor colorimetric method of Clark and Lub (8, 9) was used. It is rapid, fairly precise, requires a minimum of apparatus, and lends itself very well for a clinical study. The bicolor methods of Medalia (31) and Gillespie (15) were tried. Satisfactory results were obtained with both, but they must be standardized against the buffer method, with errors attendant upon a second standardization, and have to be prepared more often than the monocolor standards, because the colors fade.

A. Apparatus. The glassware was of pyrex brand, treated by the method of Fawcett and Acree (11), which minimizes absorption of alkali from the glass by the solutions and consequent change in pH. These precautions have been stressed by Clark (9), Schlegel and Steuber (40), Pierre and Fudge (37), and others.

The tubes for color standards and routine determinations were 15 x 100 mm.; lipless; and graded to uniform size, by running-in 10 cc. of water from a burette, marking with a diamond point the level of the meniscus, and

grouping according to similarity of position of these marks. The tubes were also marked at the 1, 2, and 5-cc. levels.

The comparator block was made from a piece of hardwood, 8 x 8 x 11 cm. Nine holes, 18 mm. in diameter and 9 cm. deep, were bored in rows of three, spaced as nearly equidistant as possible. The comparator block may be used for either monocolor or bicolor color-standards. Slots, 5 mm. deep and 25 mm. in length, were made horizontally across front and back at a distance of 35 mm. from the bottom. The slot at the front, toward the source of light, holds a piece of ground glass, which helps to diffuse light equally to all tubes. The slot at the back, toward the eye when comparing colors, holds cobalt-blue glass, which increases the differentiating ability of the eyes for the colors of certain indicators. The ground glass and the cobalt were used by Michaelis (10) in his work with nitrophenol indicators. The writer finds that these glasses are useful only when artificial light is the source of illumination, and that the cobalt-blue glass is an aid with brom-thymol blue but not with brom-cresol purple, the indicators used in this study. The density of these glasses must be selected by trial.

B. Solutions. Inasmuch as the pH range of normal resting saliva is usually between 5.5 and 7.5, it is necessary to have buffer solutions with a range slightly greater. The requirement is satisfied by the phthalate and phosphate buffers of Clark and Lub, which have a combined range in the pH scale from 4.0 to 8.0. Indicators covering the mentioned salivary range are brom-cresol purple (pH range of indicators) and brom-thymol blue (pH range of indicators). (*1*) *Solutions required:* *M*/5 potassium acid phthalate, *M*/5 potassium acid phosphate, *M*/5 sodium hydroxide, 0.4% brom-thymol blue, 0.04% brom-thymol blue, 0.4% brom-cresol purple, 0.04% brom-cresol purple, freshly boiled distilled water, distilled water.

2. Preparation of solutions. *M*/5 potassium acid phthalate, *M*/5 potassium acid phosphate, and *M*/5 sodium hydroxide solutions, and buffer mixtures, were prepared as outlined by Clark (10). *The buffer mixtures, indicator solutions, and color standard were stored in an ice-box and protected from light while not in use, to minimize the change in pH and the fading of colors. Indicator solutions: 0.4% stock solution of brom-thymol blue.*— A 0.4% aqueous alkali-salt solution of brom-thymol blue was made by adding 0.4 gram of indicator powder (National Chemical) to 17.92 cc. of *N*/20 NaOH and then making up to 100 cc. with freshly boiled distilled water. This gives a solution with a pH of 6.78, approximately the middle of the range of brom-thymol blue, and the average for normal resting saliva and freshly boiled distilled water. Fawcett and Acree (11), and others, have pointed out the necessity of adjusting the pH of the indicator solution to

approximately the middle of the range of the indicator and of the solution on which the determinations are to be made. The solution was stored in a 125-cc. pyrex bottle sealed with paraffin. *0.04% solution of brom-thymol blue.*—Prepared by making up 10 cc. of 0.4% stock solution of brom-thymol blue to 100 cc. with freshly boiled distilled water; kept in a 125-cc. pyrex bottle, sealed with paraffin. *0.4% stock solution of brom-cresol purple.*—0.4 gram of powdered dye (National Chemical) was dissolved in 22.4 cc. of $N/20$ NaOH, and made up to 100 cc. with distilled water in equilibrium with the CO_2 content of the room air. This solution is approximately at the middle of the range of brom-cresol purple, of saliva where brom-cresol purple would be indicated, and of distilled water in equilibrium with the CO_2 of the room air. It was stored in a pyrex bottle sealed with paraffin. *0.04% solution of brom-cresol purple.*—10 cc. of stock solution was made up to 100 cc. with distilled water in equilibrium with the CO_2 content of the room air; stored in a 125-cc. pyrex bottle, sealed with paraffin. *Freshly boiled distilled water.*—Ordinary distilled water was boiled until practically free from CO_2 (usually 15–20 minutes was sufficient); the pH was approximately 6.7–6.8—about the middle of the range of normal resting saliva and of brom-thymol blue; stored in a pyrex bottle to which a soda-lime tube and syphon were attached. *Distilled water in equilibrium with CO_2 content of room air.*—Ordinary distilled water, in an open vessel, was exposed to room air for several hours until it was in equilibrium with the CO_2 content of the air; the pH was approximately 5.8, or about the middle of the range of brom-cresol purple and of saliva where this indicator was used.

(*3*) *Preparation of color standards.* Nineteen lipless pyrex tubes, 15 x 100 mm., of uniform size, were placed in a rack and labeled from 5.0 to 6.2, in increments of 0.2 for the phthalates; from 5.8 to 8.0, in increments of 0.2 for the phosphates. Ten cc. of either phthalate or phosphate mixture were run into the tubes labeled with corresponding pH values. To each tube was added 0.8 cc. of 0.04 percent solution of indicator—brom-cresol purple in the case of tubes with phthalate mixture; brom-thymol blue, with phosphate mixture. The tubes were stoppered with no. 10 solid-rubber stoppers and sealed with paraffin. (Melt paraffin in a small beaker; invert the color-standard tube, and dip end into melted paraffin.)

C. Procedure for making pH determinations on saliva. (*1*) *Preparation of patient.* In any study dealing with normal resting saliva, certain precautions must be used to get saliva that approximates the normal in all respects. The term "resting saliva" is given to saliva secreted without any form of induced stimulation; that is, saliva secreted into the oral cavity as a result of normal metabolism of the glands, breathing, and ordinary move-

ments. It has been shown by Starr (41), McClelland (28), Carlson and McKinstry (5), Bunzell (3), Clark and Carter (7), and others, that "resting saliva" has a H-ion concentration lower than "activated saliva," i.e., saliva secreted by induced stimulation. Their experiments have shown that, in general, any substance introduced into the mouth—whether acid, neutral or basic, solid or liquid—alters the pH for a short time thereafter. Cannon (4), Starr (41), and others, have pointed out that fear, anger, and pain alter the saliva both qualitatively and quantitatively. Cannon (4), Mathur (26), Pickerill (36), and others, have shown that sensations of the olfactory, auditory, and visual senses may inhibit or stimulate flow of saliva, with consequent alteration in composition. The writer has attempted to eliminate these factors as much as possible in preparing the patient, realizing also the inherent danger of repression. Conditions were made as nearly normal as possible for the patient, to put him "at ease" both physically and mentally. (*2*) *Collection of specimen.* The patient was given a lipless pyrex tube and instructed to allow saliva to collect naturally in the mouth, and to expectorate it into the tube. This was facilitated with a thistle tube. Two-cc. samples were taken in most cases; when flow of saliva was extremely slow, 1-cc. samples were used. Determinations were made immediately; loss of CO_2 was probably not significant. Henderson and Millet (20), and McClelland (28), found that when determinations are made as soon as saliva is collected, loss of CO_2 is not appreciable. The procedures of boiling, dialyzing, filtering, and centrifuging the samples before making determinations were not used, the writer, Starr (41), and others, having found that the pH of resting saliva is altered thereby. These procedures may account for some disagreements in results obtained by different workers. For infants and children under three years, saliva was obtained with a specially arranged aspirator—a saliva ejector of glass was fastened with tubing to the test tube, and attached to a water pump, negative pressure drawing saliva into the tube. (*3*) *Dilution of specimen.* The specimen was diluted 1:5 with freshly boiled distilled water. Dilution in this proportion should not appreciably affect the pH. Starr (41) and McClelland (28) found no appreciable changes at low dilution; similar findings were reported by Fawcett and Acree (11), and Pierre and Fudge (37). When saliva was more acid than pH 6.0 to brom-thymol blue, a second sample was taken and diluted with distilled water in equilibrium with room air, and brom-cresol purple used for the determination. (*4*) *Determination of pH.* 0.8 cc. of 0.04 percent solution of indicator was added to the diluted sample, the tube stoppered, and the mixture shaken until color was evenly diffused. Color standards approximating the color of the sample were selected, and the

three placed in the comparator block in the front row. The sample was usually placed in the middle; the color standards, on either side. To compensate for cloudiness, tubes with 2 cc. of saliva diluted to 10 cc. with water were placed behind the two color standards. Another tube with 10 cc. of distilled water was placed behind the sample, so that light in passing through the sample also passed through the tube of distilled water, compensating thereby for the depth through which the light passed in the color standards, and in tubes with diluted saliva and no indicator. This gave three rows, two tubes in depth, through which the light had to pass. The comparator was placed in front of the source of light, with the surface of the

TABLE 1

Composite of all age-groups, showing average pH of normal resting saliva of males and females for each age-group

AGE-GROUP	MALE		FEMALE		TOTAL	
	Cases	Ave. pH	Cases	Ave. pH	Cases	Ave. pH
Infants	51	6.81	53	6.85	104	6.83
1– 6 years	115	6.76	128	6.75	241	6.75
6–10 years	122	6.81	158	6.79	280	6.80
10–20 years	489	6.76	479	6.73	969	6.74
20–30 years	170	6.79	185	6.77	355	6.78
30–40 years	127	6.69	113	6.70	240	6.69
40–50 years	171	6.73	115	6.79	286	6.76
50–60 years	263	6.77	110	6.67	373	6.76
60–70 years	188	6.76	60	6.74	248	6.76
70–80 years	104	6.73	109	6.66	213	6.70
80–90 years	25	6.86	63	6.57	88	6.63
90–100 years	1	6.60	7	6.60	8	6.60
Totals.....	1826	6.76	1578	6.73	3404	6.75

block having the ground-glass toward the light. The sample was compared in color with that of the color standards by checking them through the cobalt-blue glass. Different color-standards were substituted for those in the comparator block until an exact match was made. The pH of the sample was that of the color standard with which it matched color. One can, by interpolation, estimate to the nearest 0.1 pH unit.

IV. RESULTS. Determinations were made of the pH of normal resting saliva of 3405 persons. The subjects, all apparently healthy, ranged in age from 3 weeks to 101 years. The determinations were made throughout the day from 7 A.M. to 5 P.M. All samples were

TABLE 2

Frequency distribution of pH of normal resting saliva of males and females, at various hours, for age-groups 3 weeks to 10 years. (M = male; F = female; T = total males and females)

A. Age-group: 3 weeks to 1 year

pH RANGE		TIME OF DAY															TOTALS		
		9–10			10–11			11–12			1–2			2–3			3–4			4–5					
		M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
5.6–5.8	M	0			0			0			0			0			0			0			0		
	F		0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			0			0			0
5.8–6.0	M	0			0			0			0			0			0			0			0		
	F		0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			0			0			0
6.0–6.2	M	1			0			0			0			0			0			0			1		
	F		0			0			0			0			0			0			0			0	
	T			1			0			0			0			0			0			0			1
6.2–6.4	M	0			0			1			0			0			0			0			1		
	F		0			0			1			0			0			0			0			1	
	T			0			0			2			0			0			0			0			2
6.4–6.6	M	1			1			2			1			0			0			0			5		
	F		0			3			3			1			1			0			0			8	
	T			1			4			5			2			1			0			0			13
6.6–6.8	M	3			2			3			0			1			3			0			12		
	F		2			2			3			2			0			0			0			9	
	T			5			4			6			2			1			3			0			21
6.8–7.0	M	3			4			2			4			1			1			1			16		
	F		4			3			0			3			6			0			0			16	
	T			7			7			2			7			7			1			1			32
7.0–7.2	M	2			2			3			1			0			0			0			8		
	F		2			5			2			1			1			1			0			12	
	T			4			7			5			2			1			1			0			20
7.2–7.4	M	1			2			1			0			3			0			1			8		
	F		0			4			1			0			0			0			0			5	
	T			1			6			2			0			3			0			1			13
7.4–7.6	M	0			0			0			0			0			0			0			0		
	F		0			1			0			0			0			1			0			2	
	T			0			1			0			0			0			1			0			2
7.6–7.8	M	0			0			0			0			0			0			0			0		
	F		0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			0			0			0
Totals	M	11			11			12			6			5			4			2			51		
	F		8			18			10			7			8			2			0			53	
	T			19			29			22			13			13			6			2			104

B. Age-group: 1 to 6 years

5.6–5.8	M	0			0			0			0			0			0						0		
	F		0			0			0			0			0			0						0	
	T			0			0			0			0			0									0
5.8–6.0	M	0			0			0			0			0			0						0		
	F		1			0			0			0			0			0						1	
	T			0			0			0			0			0									1
6.0–6.2	M	1			1			0			0			0			0						2		
	F		0			1			1			0			0			0						2	
	T			1			2			1			0			0			0						4
6.2–6.4	M	1			1			0			1			0			0						3		
	F		1			0			0			2			0			0						3	
	T			2			1			0			3			0			0						6
6.4–6.6	M	4			3			1			6			0			2						16		
	F		2			4			0			7			0			0						13	
	T			6			7			1			13			0			2						29

TABLE 2—*Continued*

B. Age-group: 1 to 6 years—Continued

pH RANGE		TIME OF DAY												TOTALS		
		9–10			10–11			11–12			1–2			2–3			3–4			4–5					
		M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
6 6–6.8	M	7			7			0			9			1			4						28		
	F		12			10			4			7			3			2							38	
	T			19			17			4			16			4			6						66
6.8–7.0	M	19			13			0			11			3			6						45		
	F		9			11			6			12			6			1							45	
	T			21			24			6			23			9			7						90
7.0–7.2	M	3			2			1			1			2			1						10		
	F		5			3			1			5			3			0							17	
	T			8			5			2			6			5			1						27
7.2–7.4	M	1			0			1			3			1			1						7		
	F		2			1			0			2			2			0							7	
	T			3			1			1			5			3			1						14
7.4–7.6	M	0			1			0			0			0			3						4		
	F		0			0			0			0			0			0							0	
	T			0			1			0			0			0			3						4
7 6–7 8	M	0			0			0			0			0			0						0		
	F		0			0			0			0			0			0							0	
	T			0			0			0			0			0			0						0
Totals	M	29			28			3			31			7			17						115		
	F		32			30			12			35			14			3							126	
	T			61			58			15			66			21			20						241

C. Age-group: 6 to 10 years

5.6–5.8	M	0			0			0			0			0			0						0		
	F		0			0			0			0			0			0							0	
	T			0			0			0			0			0			0						0
5.8–6.0	M	0			0			0			0			0			0						0		
	F		0			0			0			0			0			0							0	
	T			0			0			0			0			0			0						0
6.0–6.2	M	0			0			2			0			0			0						2		
	F		0			0			1			0			0			1							2	
	T			0			0			3			0			0			1						4
6.2–6.4	M	0			0			0			3			0			0						3		
	F		2			1			0			0			0			0							3	
	T			2			1			0			3			0			0						6
6.4–6.6	M	3			3			1			4			1			0						12		
	F		11			5			1			1			3			1							22	
	T			14			8			2			5			4			1						34
6 6–6.8	M	13			4			3			5			1			0						26		
	F		10			7			6			7			8			3							41	
	T			23			11			9			12			9			3						67
6.8–7.0	M	12			9			12			2			6			0						41		
	F		9			9			6			4			6			2							36	
	T			21			18			18			6			12			2						77
7.0–7.2	M	6			3			8			3			4			0						24		
	F		11			8			1			9			5			3							37	
	T			17			11			9			12			9			3						61
7.2–7.4	M	4			3			2			1			2			0						12		
	F		4			2			4			2			2			0							14	
	T			8			5			6			3			4			0						26
7 4–7.6	M	0			0			0			1			0			0						1		
	F		0			0			0			0			0			3							3	
	T			0			0			0			1			0			3						4
7.6–7.8	M	0			1			0			0			0			0						1		
	F		0			0			0			0			0			0							0	
	T			0			1			0			0			0			0						1
Totals	M	38			23			28			19			14			0						122		
	F		47			32			19			23			24			13							158	
	T			85			55			47			42			38			13						280

TABLE 3

Frequency distribution of pH of normal resting saliva of males and females, at various hours, for age-groups 10 to 30 years. (M = male; F = female; T = total males and females)

A. Age-group: 10 to 20 years

pH RANGE		TIME OF DAY 8–9			9–10			10–11			11–12			12–1			1–2			2–3			3–4			4–5			TOTALS		
		M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
5.6–5.8	M	0			0			0			0			0			0			0			0						0		
	F		0			0			0			0			0			0			0			0						0	
	T			0			0			0			0			0			0			0								0
5.8–6.0	M	0			1			0			0			0			0			0			0						1		
	F		0			1			0			0			0			0			0			0						1	
	T			0			2			0			0			0			0			0								2
6.0–6.2	M	0			4			2			0			0			1			0			0						7		
	F		0			1			4			0			1			3			0			1						10	
	T			0			5			6			0			1			4			0			1						17
6.2–6.4	M	1			3			0			4			1			7			3			0						19		
	F		0			5			2			0			1			5			4			0						17	
	T			1			8			2			4			2			12			7			0						36
6.4–6.6	M	4			16			9			4			1			10			3			0						47		
	F		0			8			10			19			2			9			12			1						61	
	T			4			24			19			23			3			19			15			1						108
6.6–6.8	M	6			34			32			16			4			15			13			3						123		
	F		0			17			32			33			25			11			7			4						129	
	T			6			51			64			49			29			26			20			7						252
6.8–7.0	M	8			33			45			19			17			12			8			4						146		
	F		0			17			30			44			32			8			13			4						148	
	T			8			50			75			63			49			20			21			8						294
7.0–7.2	M	3			23			22			28			15			8			9			2						110		
	F		0			6			28			22			18			5			8			2						89	
	T			3			29			50			50			33			13			17			4						199
7.2–7.4	M	4			10			9			2			2			4			2			0						33		
	F		0			3			8			4			3			0			0			0						18	
	T			4			13			17			6			5			4			2			0						51
7.4–7.6	M	0			0			0			3			0			0			0			0						3		
	F		0			0			0			0			1			1			3			1						6	
	T			0			0			0			3			1			1			3			1						9
7.6–7.8	M	0			0			0			0			0			0			0			0						0		
	F		0			0			0			0			0			0			0			0						0	
	T			0			0			0			0			0			0			0			0						0
Totals	M	26			124			119			76			40			57			38			9						489		
	F		0			58			114			122			83			42			47			13						479	
	T			26			182			233			198			123			99			85			22						968

B. Age-group: 20–30 years

5.6–5.8	M	0			0			0			0			0			0			0			0						0		
	F		0			0			0			0			0			0			0			0						0	
	T			0			0			0			0			0			0			0			0						0
5.8–6.0	M	0			0			0			0			0			0			0			0			0			0		
	F		0			0			0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			0			0			0			0			0
6.0–6.2	M	0			0			0			0			0			1			0			0			0			1		
	F		0			0			0			0			0			0			0			1			0			1	
	T			0			0			0			0			0			1			0			1			0			2

TABLE 3—*Continued*

B. Age-group: 20–30 years—*Continued*

pH RANGE		TIME OF DAY																		TOTALS		
		8–9			9–10			10–11			11–12			12–1			1–2			2–3			3–4			4–5					
		M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
6.2–6.4	M	0			0			0			1			0			2			4			1			0			8		
	F		5			2			1			3			0			0			0			2			1			14	
	T			5			2			1			4			0			2			4			3			1			22
6.4–6.6	M	0			0			0			1			0			7			6			1			0			15		
	F		1			2			4			4			0			2			1			4			3			21	
	T			1			2			4			5			0			9			7			5			3			36
6.6–6.8	M	0			6			5			5			1			12			19			3			0			51		
	F		7			7			6			7			0			5			4			9			4			49	
	T			7			13			11			12			1			17			23			12			4			100
6.8–7.0	M	0			4			3			8			0			9			15			6			0			45		
	F		9			8			15			2			0			3			5			2			4			48	
	T			9			12			18			10			0			12			20			8			4			93
7.0–7.2	M	1			4			5			1			0			9			9			7			0			36		
	F		9			4			10			6			1			2			1			4			0			37	
	T			10			8			15			7			1			11			10			11			0			73
7.2–7.4	M	0			2			0			1			0			1			6			3			0			13		
	F		0			2			4			1			0			0			2			2			2			13	
	T			0			4			4			2			0			1			8			5			2			26
7.4–7.6	M	0			0			0			1			0			0			0			0			0			1		
	F		0			0			0			0			0			0			0			2			0			2		
	T			0			0			0			1			0			0			0			2			0			3
7.6–7.8	M	0			0			0			0			0			0			0			0			0			0		
	F		0			0			0			0			0			0			0			0			0			0		
	T			0			0			0			0			0			0			0			0			0			0
Totals	M	1			16			13			18			1			41			59			21			0			170		
	F		31			25			40			23			1			12			13			26			14			185	
	T			32			41			53			41			2			53			72			47			14			355

taken at least 30 minutes, and in most instances an hour or more, after meals. The cases have been separated into different age-groups. The youngest group, 3 weeks to 1 year, comprises the infants (well babies). The group, 1 to 6 years, is made up of pre-school children (infants over 1 year, and children from nurseries and kindergartens). The group 6 to 10 years includes the younger school children. Those aged 10 to 100 years have been divided into decade-groups. One case, 101 years old, is not included in the tables; the pH of the sample was 6.2. *Table 1*, a composite, shows the average pH of the different age-groups. *Tables 2* to *5* show the frequency distribution of the pH of normal resting saliva of males and females at various hours for each age-group; *table 6* is a composite for all age-groups. *Table 7* shows the number of cases in the various pH groups; the proportion of each group in the total number of cases studied; and the percentages

TABLE 4[1]

Frequency distribution of pH of normal resting saliva of males and females, at various hours, for age-groups 30 to 70 years. (M = male; F = female; T = total males and females)

A. Age-group: 30–40 years

pH RANGE		TIME OF DAY																		TOTALS		
		7–8			8–9			9–10			10–11			11–12			1–2			2–3			3–4			4–5					
		M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
5 6–5.8	M	0			0			0			0			0			0			0			0			0			0		
	F		0			0			0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			0			0			0			0			0
5.8–6.0	M	0			1			0			0			0			0			0			0			1			2		
	F		0			0			0			1			0			0			0			2			0			3	
	T			0			1			0			1			0			0			0			2			1			5
6.0–6.2	M	0			0			0			0			0			3			1			0			0			4		
	F		0			0			0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			3			1			0			0			4
6.2–6.4	M	0			2			0			0			0			4			2			0			1			9		
	F		0			0			1			0			0			0			0			0			0			1	
	T			0			2			1			0			0			4			2			0			1			10
6.4–6.6	M	0			1			0			2			1			6			4			5			0			22		
	F		0			3			2			4			3			1			7			7			0			24	
	T			0			4			2			6			4			7			11			12			0			46
6.6–6.8	M	3			2			0			1			1			9			9			3			1			31		
	F		0			4			2			2			6			4			4			12			1			35	
	T			3			6			2			3			7			13			13			15			2			66
6.8–7.0	M	3			1			2			3			2			16			11			1			1			40		
	F		0			5			9			10			4			5			2			6			0			41	
	T			3			6			11			13			6			21			13			7			1			81
7.0–7.2	M	0			1			0			1			2			3			5			0			0			12		
	F		0			0			1			0			0			1			4			0			0			6	
	T			0			1			1			1			2			4			9			0			0			18
7.2–7.4	M	0			1			0			0			1			1			1			0			0			4		
	F		0			0			0			0			0			1			0			0			0			1	
	T			0			1			0			0			1			2			1			0			0			5
7.4–7.6	M	0			0			0			0			1			0			1			0			0			2		
	F		0			0			0			0			0			0			2			0			0			2	
	T			0			0			0			0			1			0			3			0			0			4
7.6–7.8	M	0			0			0			0			0			0			1			0			0			1		
	F		0			0			0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			0			1			0			0			1
Totals	M	6			9			2			7			8			42			38			9			4			127		
	F		0			12			15			17			13			12			16			27			1			113	
	T			6			21			17			24			21			54			54			36			5			240

B. Age-group: 40 to 50 years

5 6–5.8	M	0			0			0			0			0			0			0			0			0			0		
	F		0			0			0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			0			0			0			0			0
5 8–6.0	M	0			0			0			0			0			2			1			0			0			3		
	F		0			0			0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			2			1			0			0			3
6.0–6.2	M	0			2			0			0			0			1			0			0			0			3		
	F		0			0			0			0			0			0			0			0			0			0	
	T			0			0			0			0			0			1			0			0			0			3
6.2–6.4	M	1			1			1			0			2			4			3			2			0			14		
	F		0			1			1			0			0			0			0			0			0			0	
	T			1			1			1			0			2			4			3			2			0			14

[1] A record of M2, F0, T2, for pH range 6.6–6.8 at 12–1, has been omitted from Section A.

TABLE 4—*Continued*

B. Age-group: 40 to 50 years—*Continued*

pH RANGE		TIME OF DAY									TOTALS
		7–8	8–9	9–10	10–11	11–12	1–2	2–3	3–4	4–5	
		M F T	M F T	M F T	M F T	M F T	M F T	M F T	M F T	M F T	M F T
6.4–6.6	M	0	2	1	5	5	3	6	8	1	31
	F	0	0	1	4	1	2	3	5	0	16
	T	0	2	2	9	6	5	9	13	1	37
6.6–6.8	M	1	5	3	2	10	2	10	5	1	34
	F	0	0	4	8	6	12	2	1	0	33
	T	1	5	7	10	16	14	12	6	1	72
6.8–7.0	M	0	4	1	5	2	5	16	4	3	40
	F	0	0	5	4	5	10	7	7	0	38
	T	0	4	6	9	7	15	23	11	3	78
7.0–7.2	M	1	6	0	1	2	2	6	5	1	24
	F	0	0	3	2	1	3	2	5	0	16
	T	1	6	3	3	3	5	8	10	1	40
7.2–7.4	M	1	1	0	0	0	1	7	2	1	13
	F	0	0	1	0	3	1	4	3	0	12
	T	1	1	1	0	3	2	11	5	1	25
7.4–7.6	M	0	0	0	0	0	0	1	1	1	3
	F	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	0	0	1	1	1	3
7.6–7.8	M	0	0	0	0	1	0	0	0	0	1
	F	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	1	0	0	0	0	1
Totals	M	4	21	6	13	22	20	50	27	8	171
	F	0	0	14	18	16	28	18	21	0	115
	T	4	21	20	31	38	48	68	48	8	286

C. Age-group: 50 to 60 years

5.6–5.8	M	0	0	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	0	0	0	0	0	0
5.8–6.0	M	1	0	0	0	0	0	0	0	0	1
	F	0	0	0	0	0	0	0	0	0	0
	T	1	0	0	0	0	0	0	0	0	1
6 0–6.2	M	0	3	0	1	0	2	2	1	0	9
	F	0	0	0	0	0	0	0	0	1	1
	T	0	3	0	1	0	2	2	1	1	10
6.2–6.4	M	0	1	0	0	2	9	5	2	0	19
	F	0	0	0	2	2	0	1	1	1	7
	T	0	1	0	2	4	9	6	3	1	26
6.4–6 6	M	0	3	0	2	5	5	1	2	2	20
	F	0	0	0	5	4	9	2	3	1	24
	T	0	3	0	7	9	14	3	5	3	44
6.6–6.8	M	4	10	1	8	6	7	9	12	1	58
	F	0	0	0	3	2	9	7	7	4	32
	T	4	10	1	11	8	16	16	19	5	90
6 8–7.0	M	7	11	0	8	8	10	16	15	2	77
	F	0	0	0	7	5	9	5	2	7	35
	T	7	11	0	15	13	19	21	17	9	112
7.0–7.2	M	8	5	1	4	7	6	6	7	2	46
	F	0	0	0	1	1	3	2	1	1	9
	T	8	5	1	5	8	9	8	8	3	55
7.2–7.4	M	4	1	2	2	5	6	6	1	0	27
	F	0	0	0	1	1	0	0	0	0	2
	T	4	1	2	3	6	6	6	1	0	29

TABLE 4—*Continued*

C. Age-group: 50 to 60 years—*Continued*

pH RANGE		TIME OF DAY									TOTALS
		7–8	8–9	9–10	10–11	11–12	1–2	2–3	3–4	4–5	
		M F T	M F T	M F T	M F T	M F T	M F T	M F T	M F T	M F T	M F T
7.4–7.6	M	2	0	0	0	0	0	2	0	0	4
	F	0	0	0	0	0	0	0	0	0	0
	T	2	0	0	0	0	0	2	0	0	4
7.6–7.8	M	0	1	0	0	0	0	0	0	1	2
	F	0	0	0	0	0	0	0	0	0	0
	T	0	1	0	0	0	0	0	0	1	2
Totals	M	26	35	4	25	33	45	47	40	8	263
	F	0	0	0	19	15	30	17	14	15	110
	T	26	35	4	44	48	75	64	54	23	373

D. Age-group: 60 to 70 years

5.6–5.8	M	0	0	0	0	0	0	0	0	0	0
	F	0	0	0	0	0	0	0	0	0	0
	T	0	0	0	0	0	0	0	0	0	0
5.8–6.0	M	0	0	0	0	1	2	0	0	0	3
	F	0	0	0	0	0	2	0	0	0	2
	T	0	0	0	0	1	4	0	0	0	5
6 0–6.2	M	0	2	0	0	0	1	1	1	1	6
	F	0	0	0	1	0	0	0	0	0	1
	T	0	2	0	1	0	1	1	1	1	7
6.2–6 4	M	0	1	0	0	1	5	1	1	3	12
	F	0	0	0	0	0	2	1	1	0	4
	T	0	1	0	0	1	7	2	2	3	16
6.4–6 6	M	1	2	0	0	3	7	6	1	0	20
	F	0	0	0	4	0	4	0	2	0	10
	T	1	2	0	4	3	11	6	3	0	30
6.6–6.8	M	5	4	1	1	5	8	7	3	1	35
	F	0	0	0	3	2	2	2	2	2	13
	T	5	4	1	4	7	10	9	5	3	48
6.8–7.0	M	4	6	1	8	9	11	11	6	0	56
	F	0	0	0	2	1	5	2	1	2	13
	T	4	6	1	10	10	16	13	7	2	69
7.0–7.2	M	5	8	1	1	1	3	4	7	2	32
	F	0	0	0	0	0	2	1	3	1	7
	T	5	8	1	1	1	5	5	10	3	39
7 2–7.4	M	4	1	0	1	3	3	5	1	0	18
	F	0	0	0	1	2	1	0	1	1	6
	T	4	1	0	2	5	4	5	2	1	24
7 4–7.6	M	0	2	0	0	0	0	1	1	0	4
	F	0	0	0	0	0	2	1	1	0	4
	T	0	2	0	0	0	2	2	2	0	8
7.6–7.8	M	1	0	0	0	0	1	0	0	0	2
	F	0	0	0	0	0	0	0	0	0	0
	T	1	0	0	0	0	1	0	0	0	2
Totals	M	20	26	3	11	23	41	36	21	7	188
	F	0	0	0	11	5	20	7	11	6	60
	T	20	26	3	22	58	61	43	32	13	248

TABLE 5

Frequency distribution of pH of normal resting saliva of males and females, at various hours, for age-groups 70 to 100 years. (M = male; F = female; T = total males and females)

A. Age-group: 70–80 years

pH RANGE		TIME OF DAY																TOTALS		
		7–8			8–9			10–11			11–12			1–2			2–3			3–4			4–5					
		M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
5.6–5.8	M	0			0			0			0			0			0			0			0			0		
	F		0			0			0			0			0			0			1			0			1	
	T			0			0			0			0			0			0			1			0			1
5.8–6.0	M	0			0			0			0			0			0			0			0			0		
	F		0			0			0			0			0			1			2			0			3	
	T			0			0			0			0			0			1			2			0			3
6.0–6.2	M	0			1			0			1			0			0			2			1			5		
	F		0			0			2			2			1			0			1			2			8	
	T			0			1			2			3			1			0			3			3			13
6.2–6.4	M	0			0			0			0			0			2			1			3			6		
	F		0			0			4			2			1			1			3			0			11	
	T			0			0			4			2			1			3			4			3			17
6.4–6.6	M	0			2			0			1			1			2			9			6			21		
	F		0			0			1			1			3			2			0			3			10	
	T			0			2			1			2			4			4			9			9			31
6.6–6.8	M	1			1			0			2			0			2			8			7			21		
	F		0			0			2			4			5			5			5			2			23	
	T			1			1			2			6			5			7			13			9			44
6.8–7.0	M	2			2			1			1			1			4			7			6			24		
	F		0			0			5			1			3			3			4			13			29	
	T			2			2			6			2			4			7			11			19			53
7.0–7.2	M	1			1			0			0			0			2			1			2			7		
	F		0			0			1			1			2			1			1			4			10	
	T			1			1			1			1			2			3			2			6			17
7.2–7.4	M	0			0			0			0			4			2			0			6			12		
	F		0			0			0			2			0			3			4			2			11	
	T			0			0			0			2			4			5			4			8			23
7.4–7.6	M	0			1			0			0			0			1			2			1			5		
	F		0			0			0			1			0			0			1			0			2	
	T			0			1			0			1			0			1			3			1			7
7.6–7.8	M	0			0			0			0			0			1			1			1			3		
	F		0			0			1			0			0			0			0			0			1	
	T			0			0			1			0			0			1			1			1			4
Totals	M	4			8			1			5			6			16			31			33			104		
	F		0			0			16			14			15			16			22			26			109	
	T			4			8			17			19			21			32			53			59			213

B. Age-group: 80 to 90 years

5.6–5.8	M							0			0			0			0			0			0			0		
	F								0			0			0			1			0			0			1	
	T									0			0			0			1			0			0			1
5.8–6.0	M							0			0			0			0			0			0			0		
	F								1			0			1			1			0			0			3	
	T									1			0			1			1			0			0			3
6.0–6.2	M							0			0			0			0			0			0			0		
	F								1			0			1			1			2			0			5	
	T									1			0			1			1			2			0			5
6.2–6.4	M							0			0			0			0			0			0			0		
	F								0			0			1			1			1			1			4	
	T									0			0			1			1			1			1			4
6.4–6.6	M							1			0			0			1			0			2			4		
	F								2			1			1			0			1			3			8	
	T									3			1			1			1			1			5			12

TABLE 5—*Continued*

B. Age-group: 80 to 90 years—*Continued*

pH RANGE		TIME OF DAY																TOTALS		
		7–8			8–9			10–11			11–12			1–2			2–3			3–4			4–5					
		M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
6.6–6.8	M							0			0			0			0			3			1			4		
	F								2			1			5			2			4			5			19	
	T									2			1			5			2			7			6			23
6.8–7.0	M							0			0			0			0			5			5			10		
	F								2			3			4			3			1			5			18	
	T									2			3			4			3			6			10			28
7.0–7.2	M							0			0			0			0			2			1			3		
	F								0			0			1			1			0			0			2		
	T									0			0			1			1			2			1			5	
7.2–7.4	M							0			0			0			0			1			1			2		
	F								0			1			0			0			1			1			3		
	T									0			1			0			0			2			2			5	
7.4–7.6	M							0			0			0			0			0			2			2		
	F								0			0			0			0			0			0			0		
	T									0			0			0			0			0			2			2	
7.6–7.8	M							0			0			0			0			0			0			0		
	F								0			0			0			0			0			0			0		
	T									0			0			0			0			0			0			0	
Totals	M							1			0			0			1			11			12			25		
	F								8			6			14			10			10			15			63	
	T									9			6			14			11			21			27			88

C. Age-group: 90 to 100 years

5.6–5.8	M							0			0			0			0						0			0		
	F								0			0			0			0						0			0		
	T									0			0			0			0						0			0	
5.8–6.0	M							0			0			0			0						0			0		
	F								0			0			0			0						0			0		
	T									0			0			0			0						0			0	
6.0–6.2	M							0			0			0			0						0			0		
	F								0			0			0			0						0			0		
	T									0			0			0			0						0			0	
6.2–6.4	M							0			0			0			0						0			0		
	F								0			0			0			0						0			0		
	T									0			0			0			0						0			0	
6.4–6.6	M							0			0			0			0						0			0		
	F								0			0			2			1						1			4		
	T									0			0			2			1						1			4	
6.6–6.8	M							0			0			0			1						0			1		
	F								1			1			0			0						0			2		
	T									1			1			0			1						0			3	
6.8–7.0	M							0			0			0			0						0			0		
	F								0			0			0			0						0			0		
	T									0			0			0			0						0			0	
7.0–7.2	M							0			0			0			0						0			0		
	F								0			0			1			0						0			1		
	T									0			0			1			0						0			1	
7.2–7.4	M							0			0			0			0						0			0		
	F								0			0			0			0						0			0		
	T									0			0			0			0						0			0	
7.4–7.6	M							0			0			0			0						0			0		
	F								0			0			0			0						0			0		
	T									0			0			0			0						0			0	
7.6–7.8	M							0			0			0			0						0			0		
	F								0			0			0			0						0			0		
	T									0			0			0			0						0			0	
Totals	M							0			0			0			1						0			1		
	F								1			1			3			1						1			7		
	T									1			1			3			2						1			8	

TABLE 6

Composite of all age-groups, showing frequency distribution of pH for males and females in each age-group

GROUP	3 WK.–1 YR.		1–6		6–10		10–20		20–30		30–40		40–50		50–60		60–70		70–80		80–90		90–100		TOTALS	
pH	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
5.6–5.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2
	0		0		0		0		0		0		0		0		0		1		1		0		2	
5.8–6.0	0	0	0	1	0	0	1	1	0	0	2	3	3	0	1	0	3	2	0	3	0	3	0	0	10	13
	0		1		0		2		0		5		3		1		5		3		3		0		23	
6.0–6.2	1	0	2	2	2	2	7	10	1	1	4	0	3	0	9	1	6	1	5	8	0	5	0	0	40	30
	1		4		4		17		2		4		3		10		7		13		5		0		70	
6.2–6.4	1	1	3	3	3	3	19	17	8	14	9	1	14	0	19	7	12	4	6	11	0	4	0	0	94	65
	2		6		6		36		22		10		14		26		16		17		4		0		159	
6.4–6.6	5	8	16	13	12	22	47	61	15	21	22	24	31	16	20	24	20	10	21	10	4	8	0	4	213	221
	13		29		34		108		36		46		47		44		30		31		12		4		434	
6.6–6.8	12	9	28	38	26	41	123	129	51	49	31	35	39	33	58	32	35	13	21	23	4	19	0	3	428	424
	21		66		67		252		100		66		72		90		48		44		23		3		852	
6.8–7.0	16	16	45	45	41	36	146	148	45	48	40	41	40	38	77	35	56	13	24	29	10	18	0	0	540	467
	32		90		77		294		93		81		78		112		69		53		28		0		1007	
7.0–7.2	8	12	10	17	24	37	110	89	36	37	12	6	24	16	46	9	32	7	7	10	3	2	1	0	313	242
	20		27		61		199		73		18		40		55		39		17		5		1		555	
7.2–7.4	8	5	7	7	12	14	33	18	13	13	4	1	13	12	27	2	18	6	12	11	2	3	0	0	149	92
	13		14		26		51		26		5		25		29		24		23		5		0		241	
7.4–7.6	0	2	4	0	1	3	3	6	1	2	2	2	3	0	4	0	4	4	5	2	2	0	0	0	29	21
	2		4		4		9		3		4		3		4		8		7		2		0		50	
7.6–7.8	0	0	0	0	1	0	0	0	0	0	1	0	1	0	2	0	2	0	3	1	0	0	0	0	10	1
	0		0		1		0		0		1		1		2		2		4		0		0		11	
Totals	51	53	115	126	122	158	489	479	170	185	127	113	171	115	263	110	188	60	104	109	25	63	1	7	1826	1578
	104		241		280		968		355		240		286		373		248		213		88		8		3404	

of males and females in each group. *Fig. 1* is a histogram of the average pH of the various age-groups. *Fig. 2*, a histogram and fitted curve, shows the frequency distribution of pH for 3404 cases.

v. DISCUSSION. The average pH of normal resting saliva for 3405 cases is 6.75; the range is 5.6 to 7.6. The average value—6.75—is approximately midway between the values obtained by others, as shown in the following summary, which includes values for only such

Average pH values of normal resting saliva from data of different authors, giving the number of cases and groups studied

Author	*Cases*	*Average pH*	*Groups*
McIntosh et al.....	12	5.6–5.9	Infants
Cassarato.....	100	6.35	All ages
Bunzell.....	298	6.00–6.64	Various age-groups
Starr.....	228	6.60	Children
Present author.....	3405	6.75	All age-groups
Stern.....	100	6.82	Children
Carlson et al.....	127	6.85	College men
Jonoff et al.....	412	7.00	Children
Hymanson et al.....	55	6.8–7.8	Infants

studies as were conducted on at least 100 cases (excepting two studies of infants). The age-group *3 weeks to 1 year* (*table 1*) has an average pH value of 6.83, which is appreciably higher than the general average, 6.75, for the entire group; compared with age-groups *70 to 80*, *80 to 90*, and *90 to 100*, it is 0.1 to 0.2 higher. To offer an explanation for this difference is only to conjecture. Hawkins (19), and Forbes and Gurley (13), have shown that diet influences salivary pH. The author (unpublished work) found that moderate exercise tends to make normal resting saliva more alkaline; under-exercise and strenuous exercise, more acid. The average for the age-group *3 weeks to 1 year* differs considerably from averages reported for similar groups by others—those reported by McIntosh, James and Barlow (29) for twelve infants (2 days to 11 months) ranged between 5.6 and 5.9, but the result was based on only a very small number of determinations. The author had only two values below 6.0 in this group, and in both cases suspected the low value to be due to vomitus and concomitant

increased acidity of the saliva. Hymanson and Davidsohn (21) found none more acid than 6.8, which represents the writer's average for the group. The other age-groups, from *1 to 80*, do not vary appreciably from the general average for the entire group, and require no comment so far as the age factor is concerned.

The pH averages for the age-groups *80 to 90* and *90 to 100* (*table 1*) are appreciably lower than that for the entire group, being 6.66 and 6.60, respectively. Little significance can be ascribed to the average

TABLE 7

Showing number of cases in various pH ranges, with proportion of males and females, and percentage of each sex, in total number of cases

pH	CASES	MALES	FEMALES	TOTAL CASES
range	*no.*	*per cent*	*per cent*	*per cent*
5.6–5.8 6.8–6.0	25	40	60	1
6.0–6.2	70	57	43	2
6.2–6.4	159	60	40	5
6.4–6.6	434	50	50	12
6.6–6.8	852	50	50	25
6.8–7.0	1007	54	46	30
7.0–7.2	555	56	44	16
7.2–7.4	241	62	38	7
7.4–7.6 7.6–7.8	61	64	36	2
Totals.....	3404	54	46	100

pH range	*Percentage of total cases*
6.2–7.4	95
6.4–7.2	83
6.6–7.0	55

for the group *90 to 100*, for which only eight determinations were made. Exercise possibly affords an explanation of the difference. Besides the factor of decreased exercise with increasing age, the individuals comprising these groups were mainly from institutions where exercise is at a minimum. Bunzell (3) found 28 aged women, 62 to 89 (average 74), had an average pH of 6.0; 9 aged men, 60 to 73 (average 69), an average of 6.24. These values are considerably lower than the writer's average of 6.71 for 557 cases in age-groups 60 to 100.

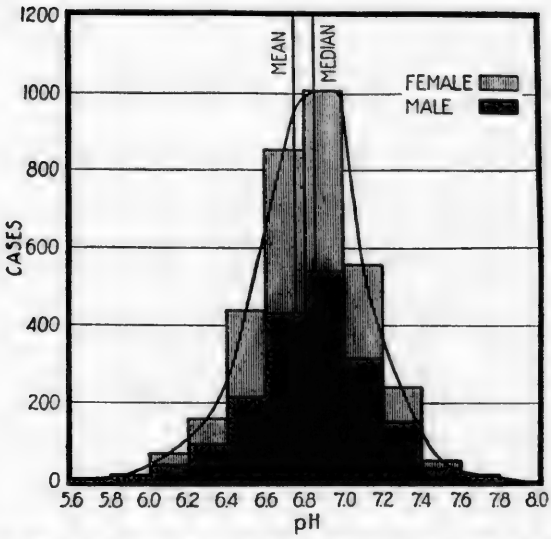

Fig. 1. Histogram and fitted curve showing frequency distribution of pH for normal resting saliva of males and females.

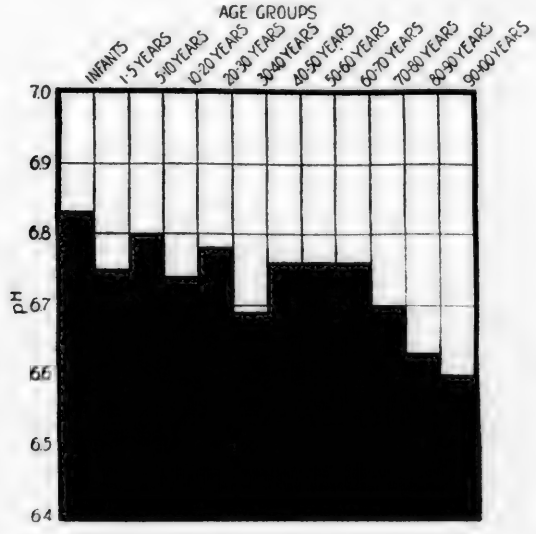

Fig. 2. Histogram showing average pH for various age-groups.

There are no significant differences in the average pH values for males and females, except in age-groups *50 to 60*, *70 to 80*, and *80 to 90* (*table 1*). In the age-group *50 to 60*, the average for the males is 6.77; for females, 6.67. To offer an explanation for this difference is, again, only conjectural. Most of the males were actively engaged in outdoor work; the females, inmates of institutions, did not do any type of work, and were not much out-of-doors, if at all. The difference between the averages for males and females in age-group *70 to 80* cannot be attributed to either diet or exercise, since both males and females were from institutions where diet and exercise are in general the same. A large proportion of the men of this group chewed tobacco. It is common knowledge that chewing, or mastication in any degree, brings forth "activated" saliva, which is more alkaline than "resting saliva." Caution was taken to avoid collecting a sample for at least 30 minutes after chewing had been stopped. It was noticed that although salivary alkalinity decreased, it never dropped to the level for those who did not chew tobacco. The same explanation must hold for the differences between the averages for males and females in age-group *80 to 90*. This does not account in any way for the lower average for the group, which must be attributed to lack of exercise. The findings are, in general, in agreement with those of Bunzell (3), who reported no difference between the averages for pH of salivas of males and females. Jonoff and Tschetunoff (23) found the pH of saliva of girls lower than that of boys. Their conclusions, however, are based on hundredths in the pH scale, distinctions which, in the hands of the writer at least, are impossible with the colorimetric method. Stern (42) reported no difference in the pH of saliva of boys and girls.

The median pH value for the entire group is slightly higher than the average or mean, being 6.84, 55 percent of the cases falling in the range 6.6 to 7.0; 83 percent, in the range 6.4 to 7.2; 95 percent, in the range 6.2 to 7.4; only 5 percent in the combined ranges of 5.6 to 6.2 and 7.4 to 7.8 (*table 7*).

The frequency distribution is practically the same for each group, the "spread" being slightly greater in the adult groups. The distribution for males and females is almost the same, except at the very extremes where there is a slight difference (males constitute 54 per-

cent, females 46 percent, of the total number of cases, *table 7*). In the range 5.6 to 6.0, males comprise 40 percent, females 60 percent, of the total number of cases. At the other end of the scale, in the range 7.4 to 7.8, the males predominate, constituting 64 percent (females only 36 percent) of the total number of cases. These differences exist for the most part in the adult groups.

VI. SUMMARY AND CONCLUSIONS. (1) Colorimetric pH determinations were made in normal resting saliva of 3405 healthy individuals, male and female, ranging in age from 3 weeks to 101 years.

(2) The mean or average pH of normal resting saliva for the entire group is 6.75, which shows that normal resting saliva is slightly acid. The median is 6.84.

(3) The average pH of normal resting saliva for the various age-groups does not vary significantly from the general average of 6.75, except in the age extremes. In the age-group 3 weeks to 1 year the average is slightly higher, in the age-groups 80 to 90 and 90 to 100 the average is slightly lower, than the general average.

(4) The average for males is 6.76, for females 6.73, showing in general that no significant sex difference exists. There were slight differences between certain age-groups (50 to 60, 70 to 80, and 80 to 90) in which the averages for the females are slightly more acid.

(5) The pH range is from 5.6 to 7.6; 55 percent of the cases fall within 6.6 to 7.0; 83 percent, within 6.2 to 7.4; only 5 percent are in the combined ranges of 5.6 to 6.0 and 7.4 to 7.8.

(6) The distribution of the values is very similar in the various age-groups, the "spread" in the range being a little greater in the adult groups. The males comprise 54 percent, the females 46 percent, of the entire group. Approximately the same percentages of total cases exist in each pH group excepting that for 5.6 to 6.2, where males make up 40 percent, females 60 percent, of the number of cases. In the range 7.2 to 7.4, the division is 62 percent males, 38 percent females; in the range 7.4 to 7.8, the division is 64 percent males, 36 percent females.

The writer expresses his sincere thanks to Dr. W. R. Bloor, Professor of Biochemistry, and to Dr. H. C. Hodge, Senior Dental-Fellow, for their advice and helpful suggestions throughout the work; to the score or more in charge of the many institutions where the work was carried out, and their staffs, for their splendid coöperation, without which the

study could not have been made; to the hundreds who willingly gave samples of their saliva; to the Rockefeller Foundation, under a grant from which the work was done.

[Additional papers in this series will appear in the next issue.—*Ed.*]

VII. REFERENCES TO LITERATURE

(1) Bloomfield, A. L., and Huck, J. G. *Bull. Johns Hopkins Hosp.*, 1920, *31*, 118.
(2) Broderick, F. W. *Am. Dent. Surg.*, 1929, *49*, 11.
(3) Bunzell, H. H. *Colgate Bull., No. 1, 2, 3, 4*, 1922.
(4) Cannon, W. B. Bodily changes in pain, hunger, fear and rage, 1929, 2nd ed., 4–10; New York.
(5) Carlson, V. R., and McKinstry, M. L. *Dent. Cosmos*, 1924, *66*, 840.
(6) Casaratto, G. *La Stomatologia*, 1927, *25*, 461.
(7) Clark, G. W., and Carter, K. L. *Jour. Biol. Chem.*, 1927, *73*, 391.
(8) Clark, W. M., and Lub, H. A. *Ibid.*, 1916, *25*, 479.
(9) Clark, W. M., and Lub, H. A. *Jour. Bact.*, 1917, *2*, 1, 109, 191.
(10) Clark, W. M. The determination of hydrogen ions, 1928, 3rd ed., 131; Baltimore.
(11) Fawcett, E. H., and Acree, S. F. *Jour. Bact.*, 1929, *17*, 163.
(12) Foa, C. *Arch. fisiol.*, 1905, *3*, 369.
(13) Forbes, J. C., and Gurley, W. E. *Jour. Dent. Res.*, 1932, *12*, 637.
(14) Gans, L. R. *Jour. Am. Dent. Assoc.*, 1926, *13*, 222.
(15) Gillespie, L. J. *Jour. Am. Chem. Soc.*, 1920, *42*, 742.
(16) Gillespie, L. J. *Jour. Bact.*, 1921, *6*, 399.
(17) Graham, L. W. *Dent. Cosmos*, 1919, *61*, 409.
(18) Hanke, M. T. Diet and dental health, 1933, 112; Chicago.
(19) Hawkins, H. *Jour. Am. Dent. Assoc.*, 1929, *16*, 781.
(20) Henderson, M., and Millet, J. A. P. *Jour. Biol. Chem.*, 1927, *73*, 559.
(21) Hymanson, A., and Davidsohn, H. *Am. Jour. Dis. Child.*, 1923, *25*, 302.
(22) Jones, W. H. S. *Hippocrates*, 1923, *1*, 231; London.
(23) Jonoff, E. M., and Tschetunoff, N. *Jahrb. Kinderh.*, 1929, *123*, 339.
(24) Kirk, E. C. *Jour. Allied. Dent. Soc.*, 1914, *9*, 186.
(25) La Farga, J. V. *Comp. rend. Soc. de Biol.*, 1922, *86*, 412.
(26) Mathur, S. N. *Indian Med. Gaz.*, 1930, *65*, 386.
(27) McClelland, J. R. *Am. Jour. Physiol.*, 1922, *63*, 127.
(28) McClelland, J. R. *Dent. Cosmos*, 1924, *66*, 425, 751.
(29) McIntosh, J., James, W. W., and Lazarus-Barlow, P. *Brit. Jour. Exper. Path.*, 1925, *6*, 260.
(30) McKeag, R. H. *Brit. Dent. Jour.*, 1928, *49*, 346.
(31) Medalia, L. S. *Jour. Bact.*, 1920, *5*, 441.
(32) Medalia, L. S. *Ibid.*, 1922, *7*, 589.
(33) Michaelis, L., and Pechstein, H. *Biochem. Ztschr.*, 1914, *69*, 77.
(34) Miller, W. D. The micro-organisms of the human mouth, 1878, 2nd ed., 66; London.
(35) Neuburger, Max. History of medicine, 1909, 141; London.
(36) Pickerill, H. P. The prevention of dental caries and oral sepsis, 1924, 3rd ed., 140; New York.

(37) PIERRE, W. H., AND FUDGE, J. F. *Jour. Am. Chem. Soc.*, 1928, *50*, 1254.
(38) POPPER, E., AND HOFFNER, F. *Deutsche Med. Wochenschr.*, 1925, *51*, 561.
(39) RICH, G. J. *Quart. Jour. Exper. Physiol.*, 1927, *17*, 53.
(40) SCHLEGEL, J. W., AND STEUBER, A. H. *Indust. and Eng. Chem.*, 1927, *19*, 631.
(41) STARR, H. E. *Jour. Biol. Chem.*, 1922, *54*, 43.
(42) STERN, A. R. *Dent. Cosmos*, 1931, *73*, 1017.
(43) STERN, H. T. *Jour. Biol. Chem.*, 1925, *65*, 677.